Oral Presentations

Protection of Vulnerable Road Users

Tuesday, June 9, 2015 | 8:30 a.m.-12:30 p.m.
Chairperson:Suzanne Tylko, Canada | Co-Chair: Jim Hand, United Kingdom | TRACK A | Room: F3

PAPERNO.15-0051-O

Integrated Bicyclist Protection Systems - Potential of Head Injury Reduction Combining Passive and Active Protection Systems

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ABSTRACT

In recent years both pedestrian passive and active safety systems, such as pedestrian bonnets/airbags and autonomous braking, have emerged on the market and are estimated to be effective to reduce injury of vulnerable road users in car crashes. A natural next step is to develop similar protection systems for bicyclists. The aim of this study was to investigate the potential bicyclist head injury reduction from passive and active protection systems compared to an integrated system.

The German In-Depth Accident Study (GIDAS) database was queried from 1999 to 2014 for severely (AIS3+) head injured bicyclists when struck by passenger car fronts. This resulted in 34 cases where information was sufficient for both the pre-crash and the in-crash part of the event. The default passive protection system was designed to mitigate head injuries caused by the bonnet area, A-pillars, and the lower windscreen (instrument panel) area (deployable hood and windshield airbag). To estimate the hood and airbag performance risk reduction functions were used based on experimental tests with and without the systems. The active protection system was an autonomous braking system, which was activated one second prior to impact if the bicyclist was visible to a forward-looking sensor. Maximum speed reduction was estimated using road condition information in each case. The integrated system was a direct combination of the passive and active protection systems. Case by case the effect from each of the active, passive and integrated systems was estimated. For the integrated system, the influence of the active system on the passive system performance was explicitly modelled in each case. A sensitivity analysis was performed varying the coverage area of the passive protection system and the activation criteria of the active system.

The integrated system resulted in 29%-62% higher effectiveness than the best single system of active respectively passive protection system in reducing the number of bicyclists sustaining severe (AIS3+) head injuries. These values were statistically tested and found to be significant. The study is based on representative data from Germany, but may not be representative to countries with a different car fleet or infrastructure. This study indicates that integrated systems of passive and active vulnerable road user countermeasures offer a significantly increased potential for head injury reduction compared to either of the two systems alone.

PAPERNO.15-0059-O

A New Strategy to Enhance Traffic Safety in Developing Countries

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ABSTRACT

The rapid expansion of motor vehicle use in developing countries resulted in a sharp rise in road traffic–related deaths and injuries. The UN General Assembly recognized road deaths and injuries as a global epidemic since 2003. More than 90% of the 1.2 million people who die each year in traffic related crashes are from the developing countries in which more than 51% are vulnerable road users.

The Kurdistan region in Iraq has been chosen for this study where the number of registered vehicles has increased exponentially in the last decade, and the official number of fatalities in 2013 was 1,114. This number, however, is highly underreported; the actual figure of fatalities is estimated to be 100% more than the reported number according to World Health Organization. Pedestrians in the region are not separated from vehicles even on high speed roads, in front of schools, bus stops, parks and commercial areas. In addition, driving education and risk assessment is poor among drivers. A pre-study showed that only 5% of the current drivers in the largest city in Kurdistan, Erbil, know how to use a roundabout. Moreover, 0%, 1% and 12% could read and were knowledgeable about the signs of “One-way”, ”Give-Away” and“ No-Entrance” respectively. The driving test and training systems are inadequate and inconsistent in the cities of Kurdistan. The tests are performed in an isolated and controlled environment separate and far away from the everyday traffic. Moreover, the road network is non-standard and is lacking alignment and signs.

This study evaluates current traffic safety conditions in Kurdistan, and then proposes a new strategy to change the current driving license test system to a more realistic and educational test that is fair and promotes safe traffic flow. The new approach, in this study, is based on a new standard driving test and training system based on the 4 E’s model which stands for: Engineering, Education, Enforcement, and Encouragement. The new proposed tests will be conducted on a limited, predefined, standardized and heavily monitored route within existing traffic environment.

This new testing system will focus on educating large groups of university students how to operate their vehicles more efficiently and safely. Moreover, the route within the existing road infrastructure that will be upgraded to standard and heavily monitored also allows licensed drivers, optionally or through an enforcement program, to retrain and experience driving on standard routes gradually leading to an improvement in drivers’ awareness. The standard route can also be used as a model and starting point to successively standardize the current road network and when constructing new roads.

PAPERNO.15-0084-O

CAR OR GROUND: WHICH CAUSES MORE PEDESTRIAN INJURIES?

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ABSTRACT

The aim was to study the cause of the injuries of pedestrians when hit in frontal impacts by a vehicle. Depending on the impact speed, the type and severity of the injuries may be due partly to the vehicle and partly to the road/ infrastructure, when falling down. The study took into account the projection distance and the age of pedestrians. The work has been supported by FSR (Fondation Sécurité Routière).

All the accident cases were reviewed by an expert committee composed by physicians and accident analysis experts. For each wounded pedestrian, the injuries were reviewed in order to determine their causing mechanism taking into account the accident occurrence circumstances, the vehicle deformations and the clues on the road or infrastructure.

The data base was a sample of 100 in-depth investigations and reconstructions of accidents from years 2009 to 2011 involving at least one injured pedestrian hit by a vehicle and continuously collected in a 20 km diameter area in the south of Paris (France). The accident analysis team was called with the emergency team on field where the data were collected.
In the sample, 89 pedestrians were injured in a frontal impact. For 83 of them, it was possible to evaluate the vehicle speed during the impact. In 12% of the cases the speed exceeded 50 km/h and all the pedestrians were severely injured (MAIS3+: pedestrian with at least one injury scored above AIS3) with a high projection distance. Therefore, we focused on frontal impact with vehicle speed below 50 km/h. In this configuration, considering injuries AIS2+, the head was the most often injured (53%) and then the lower limbs (21%). Among the wounding elements, the ground was incriminated in 27.5% of the cases, then the bonnet (22%), the windshield (17%) and the bumper (15.5%).When the vehicle speed was below 30 km/h, more than half of the injuries AIS2+ observed were caused by an impact with the ground. There was a compounding effect of age.

Though the sample is not representative of all French pedestrian accidents, it allows categorizing these accidents depending on the impact speed. For each speed range, the main causal factor of the injuries was determined. The vehicle speed was the major factor in the determinism of the injury severity of pedestrians involved in frontal impact, firstly by direct impact secondly by increasing the projection distance and thus the severity of injuries due to ground impact. Primary safety systems should reduce the severity of pedestrian injuries by decreasing the impact speed.

PEER REVIEW: PAPER NO. 15-0114-O

Creating Pedestrian Crash Scenarios in a Driving Simulator Environment

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ABSTRACT

Research Question/Objective

Currently, in the United States, pedestrian injuries account for 3.3 % of all traffic injuries, but disproportionately, pedestrian fatalities account for roughly 13% of traffic related deaths. In many other countries, pedestrians make up more than 50% of those injured and killed in crashes. The research project examined driver response to crash imminent situations involving pedestrians in a high-fidelity, full motion driving simulator. Driving simulators offer a safe environment in which to test driver response and offer the advantage of having virtual pedestrian models that move realistically unlike test track studies which by nature must use pedestrian dummies on some moving platform.

Methods and Data Sources

An analysis of pedestrian crash trajectories, speeds, roadside features, and pedestrian behavior was used to create 18 unique crash scenarios representative of the most frequent and most costly crash types. For the study reported here, we only considered scenarios where the car is traveling straight since these represent 99% of fatalities. We are also interested in how driver expectancy affects response to pedestrian conflicts. We manipulated driver expectancy in two ways: by including unmarked mid-block (unexpected) and marked intersection (expected) crossings and by directing the drivers gaze toward or away from the emerging pedestrian conflicts through the use of visually conspicuous objects to attract attention. We tested two levels of pedestrian walking speed: 1.1 and 2.5 meters/sec; these levels were drawn from engineering standards for signal timing and observational data from crosswalks. We included scenarios where pedestrians approached the road from both the left and right side of the road. This resulted in a 2 (crossing location) x 2 (driver expected gaze direction) x 2 (walking speed) x 2 (direction of approach) within subjects experimental design. In addition, two scenarios were included where a pedestrian was walking alongside the road with the car going straight. Three visual environments for the scenarios were used to provide a variety of roadside environments and speed: a 20-30 mph residential area, a 55 mph rural undivided highway and a 40 mph urban area. Forty-eight participants aged 18-75 drove the forty minute scenarios.

Results
Driver eye gaze position was measured along with steering, brake, and throttle input. Resulting vehicle trajectories are generated through the vehicle dynamics model of the driving simulator. We have completed data collection as of June 2014 and will have the results analyzed in time to submit a full paper in November.

Discussion and Limitations
As with any study of crash-imminent events, it is likely that drivers became more cautious over the course of the drive as they experienced critical events. Results will be examined for time order effects. Two different drive orders were created to counterbalance the event sequence. In order to mask the critical events, the scenarios included many other innocuous pedestrian and vehicle movements.

Conclusion and Relevance to session submitted
The results of the research can be used to inform pedestrian crash avoidance/mitigation systems by identifying driver error, driver response time, and driver response choice (i.e. steering vs. braking).

PAPER NO. 15-0141-O

Benefits Assessment of Autonomous Emergency Braking Pedestrian Systems Based on Real World Accidents Reconstruction

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ABSTRACT
Despite the success in reducing Spanish traffic fatalities by 65 percent in the past decade (2004 - 2013), pedestrian fatalities only have diminished by 45% (decreased by 35% in urban areas).
This paper describes the main findings of a coordinated study performed by INSIA-UPM aimed to assess the potential influence of two active safety systems, a brake assist system (BAS) and an autonomous emergency braking system (AEB), in vehicle-pedestrian collisions through reconstruction of real-world accidents occurred in the city of Madrid (Spain). A total number of 50 vehicle-pedestrian collisions have been in-depth investigated following a common methodology, including on the spot data collection, analysis and reconstruction to estimate the collision speed and the pedestrian kinematics. Every single case has been virtual simulated twice using PC-Crash® software: the first is a reconstruction of the real accident and the second is a simulation in which the operation of active safety systems is emulated.
The performance of the BAS system acts together with the antilock braking system (ABS). The AEB system emulated in this paper through computer simulations is based on the DaimlerChrysler's PROTECTOR system.

The benefit is assessed in terms of both collision speed and Injury Severity Probability (ISP) by comparing the reduction of their values from the real conditions to the virtual simulations. The pedestrian ISP was estimated, depending on the collision speed and the pedestrian head impact point, using a specific application to calculate its value based on the results of head form impact laboratory tests.
The findings show that in several cases the collision could be avoided by implementing the active safety systems (12% if the vehicle was fitted with BAS+ABS system; 42% with PROTECTOR system); and it would reduce their consequences in terms of the estimated ISP. It was also found that in few cases a low reduction of the collision speed would increase the head injury severity (10%).
Further research should include injury information and/or estimation (HIC). Other limitations are the sample size (only one city and frontal collisions) and no unhurt accidents have been included.
The injury severity assessment within this study only considers head impacts to the front surface of the vehicle, injuries provoked by subsequent impacts were not taken into account. Hence it can be an interesting subject for further research.

This is new because: it is a prospective assessment of active safety systems and autonomous emergency braking systems; it is based on accurate reconstructions, highly detailed parameters; the behavior of the system is simulated according to design parameters.
Multi-disciplinary approaches such as this study make the identification of critical parameters easier and simplify the development of practical solutions by quantifying their potential impact on future actions to improve pedestrian safety. The active safety braking pedestrian systems have a potential benefit in real conditions. It also has limitations so we cannot rely just on it. It has to act together with other passive features and the driver has to keep aware. This methodology can serve to test the benefit of forthcoming active safety technologies.

PAPERNO.15-0169-O

Fatal Urban Cyclist Collisions with Lorries: An in-Depth Study of Causation Factors and Countermeasures Using a System-Based Approach

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ABSTRACT
In the UK and other countries cyclists are the only group of road users with increasing fatalities and cyclist protection has become a high priority both to reduce the risks of cycling and the perception of risks amongst cyclists. The objective of this study is to apply a systems approach to a causation analysis of fatal crashes in order to identify key risk factors and countermeasures associated with all vehicles involved, the infrastructure, road users themselves and road safety management.
The paper presents an analysis of fatal cyclist collisions that took place in London in the years 2007 to 2011. Case materials included police reports, witness statements, vehicle inspections, scene plans and photographs, collision reconstructions, post-mortem and other medical reports. The sample comprised a total of 53 fatal cyclist collisions that occurred during the five year period.
The most common collision type resulting in a fatal cyclist was an impact with a large vehicle >3.5T including 27 lorries and 3 buses. The most common manoeuvre involved the large vehicle turning left resulting in a low speed interaction with the cyclist. Generally impacts occurred to the front left side or left front side of the truck (24 cases, 89%). Insufficient direct vision of the cyclist was a factor in all of these cases with additional risks associated with driver attention and mirror limitations. The availability of Class V side and Class VI front mirrors did not prevent all fatalities.
12 (45%) of the lorries were equipped with side guards while 11 were exempt, however all of the fatally injured cyclists were on the ground before any side-guard interaction could have occurred and side guards were not seen to be effective in this sample.

PAPERNO.15-0286-O

Development of a Test Procedure for Driver Assist Systems Addressing Accidents between Right Turning Trucks and Straight Driving Cyclists

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ABSTRACT
Accidents between right turning trucks and straight riding cyclists often show massive consequences. Accident severity is much higher than in other accidents. The situation is critical especially due to the fact that, in spite of the six mirrors that are mandatory for ensuring a minimum field of sight for the truck drivers, cyclists in some situations cannot be seen or are not seen by the driver. Either the cyclist is overlooked or is in a blind spot area that results from the turning manoeuvre of the truck and its articulation if it is a truck trailer or truck semitrailer combination.
At present driver assistance systems are discussed that can support the driver in the turning situation by giving a warning when cyclists are riding parallel to the truck just before or in the turning manoeuvre. Such systems would

generally bear a high potential to avoid accidents of right turning trucks and cyclists no matter if they ride on the road or on a parallel bicycle path. However, performance requirements for such turning assist systems or even test procedures do not exist yet. This paper describes the development of a testing method and requirements for turning assist systems for trucks.

The starting point of each development of test procedures is an analysis of accident data. A general study of accident figures determines the size of the problem. In-depth accident data is evaluated case by case in order to find out which are representative critical situations. These findings serve to determine characteristic parameters (e.g. boundary conditions, trajectories of truck and cyclist, speeds during the critical situation, impact points). Based on these parameters and technical feasibility by current sensor and actuator technology, representative test scenarios and pass/fail-criteria are defined.
The outcome of the study is an overview of the accident situation between right turning trucks and straight driving cyclists in Germany as well as a corresponding test procedure for driver assistance systems that at this first stage will be informing or warning the driver. This test procedure is meant to be the basis for an international discussion on introducing turning assist systems in vehicle regulations.

PAPERNO.15-0300-O

Sensitivity of Q10 and Q6 Chest Measurements to Restraint and Test Parameters

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ABSTRACT

Upcoming test procedures and regulations consider the use of Q-dummies. Especially Q6 and Q10 will be introduced to assess the safety of child occupants in vehicle rear seats. Therefore detailed knowledge of these dummies is important to improve safety. As recent studies have shown, chest deflection measurements of both dummies are influenced by parameters like belt geometry. This could lead to a non optimized design of child restraint systems (CRS) and belt systems. The objective of this study is to obtain a more detailed understanding of the sensitivity of chest measurements to restraint parameters and to investigate the possibilities of chest acceleration as an alternative for the assessment of chest injury risks.
A study of frontal impact sled tests was performed with Q6 and Q10 in a generic rear seat environment on a bench. Belt parameters like modified belt attachment locations were varied. For the Q6 dummy, different positioning settings of the CRS (booster with backrest) and of the dummy itself were investigated. The Q10 dummy was seated on a booster cushion. Here the position of the upper belt anchorage point was varied. To simulate the influence of vehicle rotation in the ODB crash configuration, the bench was pre-rotated on the sled in additional tests with the Q10. This configuration was tested with and without pretensioner and load limiter.
Chest deflection in Q6 showed a high sensitivity to changes in positioning of the CRS and the dummy itself. A more slouched position of the CRS or dummy resulted in a reduction of measured chest deflection, whereas chest acceleration increased for a more slouched position of the CRS. Chest deflection in Q10 is sensitive to belt geometry as already shown in other studies. In a more outboard position of the shoulder belt anchorage the measured chest deflection is higher. Chest acceleration shows the opposite tendency, which is highest for the rearmost location of the upper belt anchorage. On a pre-rotated bench the highest chest deflection within this test series was observed without load limiter/pretensioner and an outboard belt position. By optimizing the belt location and the use of pretensioner/load limier the chest deflection was significantly reduced.
For the Q6 a criterion based on chest acceleration as well as deflection measured at two locations might be the most reliable approach, which requires further research with an additional upper deflection sensor. In the Q10 the measured chest deflection does not always correctly reflect the severity of chest loading. The deflection is depending on initial belt position and restraint parameters as well as test conditions, which result in different directions of belt migration. A3ms chest acceleration might be a better indicator for severity of chest loading independent of different conditions like belt geometries. However, in some cases the benefit of an optimized restraint system could only be shown by deflection. These findings suggest that further research is needed to identify a chest injury assessment method, which could be based on deflection as well as acceleration or other parameters related to belt to occupant interaction.

PAPERNO.15-0319-O

Guidelines for Pedestrian Friendly Windscreen Designs Considering Probabilistic Fracture Behaviour of Glass

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ABSTRACT

If adult pedestrians are being struck by passenger cars with short bonnets, head contact usually occurs in the windscreen area. In test procedures for regulation and consumer protection, this impact type is being assessed using so-called pedestrian head impactors. The head injury risk is being evaluated based on the acceleration signal using the so-called Head Injury Criterion (HIC). Corresponding experimental impactor tests in the windscreen center show large scatter. Main reason for the observed scatter is the fracture initiation of glass as already published in several studies (Kinsky 2005). Thus, for a head impact in the windscreen center an early fracture initiation results in a small head injury risk, while a late fracture initiation increases the injury risk significantly (Ries 2005). In the design of measures for the enhancement of vehicle sided pedestrian safety, this scatter is currently neglected.

Based on a theoretical description of the probabilistic fracture mechanics of glass, a methodology for designing pedestrian friendly windscreens considering the probabilistic fracture mechanics of glass will be described in the present paper. This methodology consists of two steps. First, the probability for certain fracture initiation times are assessed, considering probabilistic fracture mechanics and the tensile stress distribution on the glass surfaces during head impact. In a second step, the head injury risks for the different fracture initiation times are evaluated.

In order to show the potential impact of the described methodology, a windscreen of a vehicle model is being assessed and optimized. The findings of this optimization process are being used to derive guidelines for pedestrian friendly windscreens.

PAPERNO.15-0330-O

Is Comfort Important for Optimal Use of Child Restraints?

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ABSTRACT

Suboptimal restraint use, particularly the incorrect use of restraints, is a significant and widespread problem among child vehicle occupants, and increases the risk of injury. Previous research has identified comfort as a potential factor influencing suboptimal restraint use.

Both the real comfort experienced by the child and the parent's perception of the child's comfort are reported to influence the optimal use of restraints. Problems with real comfort may lead the child to misuse the restraint in their attempt to achieve better comfort whilst parent-perceived discomfort has been reported as a driver for premature graduation and inappropriate restraint choice. However, this work has largely been qualitative. There has been no research that objectively studies either the association between real and parental perceived comfort, or any association between comfort and suboptimal restraint use. One barrier to such studies is the absence of validated tools for quantifying real comfort in children. We aimed to develop methods to examine both real and parent-perceived comfort and examine their effects on suboptimal restraint use.

We conducted online parent surveys (n=470) to explore what drives parental perceptions of their child's comfort in restraint systems (study 1) and used data from field observation studies (n=497) to examine parent-perceived comfort

and its relationship with observed restraint use (study 2). We developed methods to measure comfort in children in a laboratory setting (n=14) using video analysis to estimate a Discomfort Avoidance Behaviour (DAB) score, pressure mapping and adapted survey tools to differentiate between comfortable and induced discomfort conditions (study 3).
Preliminary analysis of our recent online survey of Australian parents (study 1) indicates that 23% of parents report comfort as a consideration when making a decision to change restraints. Logistic regression modelling of data collected during the field observation study (study 2) revealed that parent-perceived discomfort was not significantly associated with premature graduation. Contrary to expectation, children of parents who reported that their child was comfortable were almost twice as likely to have been incorrectly restrained ($p<0.01$, 95% CI 1.24 - 2.77).
In the laboratory study (study 3) we found our adapted survey tools did not provide a reliable measurement of real comfort among children. However our DAB score was able to differentiate between comfortable and induced discomfort conditions and correlated well with pressure mapping.

Our results suggest that while some parents report concern about their child's comfort, parent-reported comfort levels were not associated with restraint choice. If comfort is important for optimal restraint use, it is likely to be the real comfort of the child rather than that reported by the parent. The method we have developed for studying real comfort can be used in naturalistic studies involving child occupants to further understand this relationship.
This work will be of interest to vehicle and child restraint manufacturers interested in improving restraint design for young occupants as well as researchers and other stakeholders interested in reducing the incidence of restraint misuse among children.

PAPERNO.15-0332-O

Mechanisms of Head and Neck Injuries Sustained by Helmeted Motorcyclists in NSW, Australia

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ABSTRACT

The wearing of a standard-approved motorcycle helmet has been the most significant step in reducing fatal and serious injury among motorcyclists worldwide. Mandatory helmet use for motorcyclists is now in place in many parts of the world. Nevertheless, some researchers have observed a high percentage and duration of hospitalisations in helmet-protected motorcyclists with the long-term outcome considerably influenced by head injury severity. The objective of this study was to investigate head and neck injuries sustained by helmeted motorcyclists in real world crashes and define the circumstances which result in injury.

Data were collected by in-depth crash investigations of motorcyclist crashes in NSW, Australia. The crash investigations included inspections of the accident scene, the crash involved motorcycle and the helmet. Where possible, detailed helmet examination including helmet disassembly was performed to identify all crash related damage. The type of damage, damage location and damage severity on the helmets were recorded. The major head and neck injury types sustained by these helmeted riders were analysed for crash and helmet damage related factors which influenced the incidence of injury.

Due to the recruitment procedures used, participants in this study were biased towards lower severity head injuries. A head injury was sustained in 23.9% of cases but serious (AIS 3+) head injury was sustained in only 2.3%. There was neck injury in 9.1% of cases but no serious (AIS 3+) neck injuries. The main head and neck injury types by frequency were superficial injury (13.6%), "diffuse" type brain injury (13.6%), facial/dental fracture (4.5%) and cervical spine fracture (4.5%).

Helmet damage was observed in the majority of cases (86.4%) suggesting successful injury prevention in many instances. A high proportion of observed impact damage was to the front of the helmet (78.5% of cases), particularly the chin bar and visor of full-face helmets. Impact damage associated with a predominantly tangential force onto the head was more common than radially directed force damage.

Superficial head injury and facial/dental fractures was significantly more common ($p < 0.01$) in riders who were wearing open face helmets, where the face and chin are exposed to direct impact, compared to full face protected riders. There were significantly more cervical spine fractures in cases with damage indicative of a radially directed force ($p = 0.036$) than where damage indicated a tangentially applied force. The circumstances resulting in "diffuse" brain injuries could not be clearly defined by the data in this study due to the small number of riders with this injury.

The results highlight potential areas for improving the head and neck protection offered to motorcyclists including extending the required region of coverage, particularly to the face, and through mitigating the effect of tangential impacts on the helmet. Given the high frequency of diffuse intracranial injury even in lower severity head injury cases, assessment of helmet effectiveness should use performance criteria reflecting the mechanisms of this type of injury.

PAPER NO. 15-0358-O

Test Procedures and Results for Pedestrian AEB Systems

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ABSTRACT
Euro NCAP will start to test pedestrian Automatic Emergency Braking Systems (AEB) from 2016 on. Test procedures for these tests had been developed by and discussed between the AsPeCSS project and other initiatives (e.g. the AEB group with Thatcham Research from the UK). This paper gives an overview on the development process from the AsPeCSS side, summarizes the current test and assessment procedures as of March 2015 and shows test and assessment results of five cars that had been tested by BASt for AsPeCSS and the respective manufacturer.
The test and assessment methodology seems appropriate to rate the performance of different vehicles. The best test result - still one year ahead of the test implementation - is around 80%, while the worst rating result is around 10%. Other vehicles are between these boundaries.

PAPER NO. 15-0375-O

Countermeasures to Address Misuse in Child Restraint Installations: from Technical Solutions to Real World Evaluation

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ABSTRACT
Misuse has been reported in various studies as an important issue in countries where local legislation requires a mandatory use of child restraint systems. It has been shown that the rate of incorrect fitting of the CRS to the car may vary between 60 to 80% (1 Bendjellal, 2006).
However research has not confirmed that all misuse scenarios result in critical occupant loading but a combination of several misuse situations may lead to an improper occupant restraint (2 Bilston, Brown, 2011). It is therefore important to develop technical solutions aiming at reducing the risk of misuse in real-world. Slack in vehicle seat belts when

securing the CRS to the vehicle and improper occupant restraint within the CRS are among the top 5 misuse situations according to Bennett study (3 Bennett, 2011) and in NHTSA 2005 survey (4 NHTSA, 2006).
Two technical solutions are presented in this paper, these are:

- A system (called A) that enables improving the attachment of the CRS to the vehicle by assisting the user to tighten properly the vehicle seatbelt
- A system (called B) that was developed: to improve the attachment of the CRS to the vehicle by tightening the vehicle seat-belt (mechanical solution); and (for harness seats) to reduce slack in the harness in riding conditions (electronic solution).

Operating modes of both systems are described. User trials were conducted to assess further the functionality of the systems as well as getting consumer feedback when utilizing them in real world. Key findings from these are also provided in the paper. Both systems show promising results in terms of assisting the users in installing CRSs.

PAPERNO.15-0391-O

Pedestrian Response with Different Initial Positions during Simulated Impact with a Mid-Sized Sedan

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ABSTRACT

Real-world pedestrian impacts occur with highly-variable or unknown initial conditions of the pedestrian. However, experimental pedestrian tests and computational pedestrian impact simulations mainly focus on the response of the subject using specific initial conditions. The objective of this study is to investigate computationally the influence of posture and impact direction angle on pedestrian response during an impact. The 50th male THUMS pedestrian model was integrated with a mid-sized sedan finite element model initially travelling at 40 km/h. The influence of the pedestrian position during impact was investigated by varying 9 orientations (relative to the vehicle) and 3 standing/gait postures, for a total of 27 impact configurations simulated. Pedestrian kinematics and injury were assessed and compared across all simulations. Substantial variations were observed on the pedestrian torso rotation (-68.9°~57.6°), and head impact conditions (head impact time 111~139 ms, and head impact velocity 10.7~15.3 m/s). The head impact velocity was found to correlate with the impact direction angle, where facing towards or away from the vehicle would result in greater head impact velocity than when struck in a purely-lateral impact.

PAPERNO.15-0418-O

Implication of Children in Road Accidents in France in 2011

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ABSTRACT

This study intends to present the analysis of all road accidents that occurred in France during the year 2011 in which children (0-13y incl.) have been involved. Based on the data collected and coded in the French safety project (VOIESUR) accidents with children have been analysed by experts. Then, these data have been weighted to be representative of the French situation.

The paper proposes an analysis of the accident data for 5 categories of road users that are light vehicle occupants, pedestrians, cyclists, motorbike passengers and buses and coaches' occupants. A distribution of the different parameters of the accident and its outcomes such as the children's injury severity is available per different road user categories.

The repartition of children across the previously described user categories shows that the most common accident for children is being light vehicle occupants (64%), then cyclists (17%) and finally pedestrians (15%). Buses and PTW occupants are representing a very small proportion (approximately 2% each).

On the 101 fatally injured children, the repartition is different and as follow: 61% are light vehicle occupants, 11% are cyclists and 26% are pedestrians. No power two wheels (PTW) passengers or coach and bus occupants have been fatally injured in 2011 in France. The remaining 2% are not belonging to any of these categories of road users.
For each category, a comparison of accident data between fatal cases and the others is proposed ending in a list of some remarkable differences. Countermeasures for fatal accidents are also proposed in each respective category.
For light vehicle occupants, the analysis of usual data such as infrastructure and journeys have been completed by a sociological profile of children's drivers and specific psychological items such as alcohol and drug consumption, atmosphere in the vehicle. Concerning children involved in cars, the sample size for children in cars is 654 that once weighted to make it representative of reality correspond to 17748 children including 62 that were killed. Evidence of a restraint system used by children has been coded for 69% of children, but in only 44% of the cases, the restraint system was appropriate and correctly used.

For children in the other road user categories, the analysis is a little bit more limited but it includes the age distribution, infrastructure and journeys data, the responsibility of involved parts (including children). The presence of protection device such as helmets: it is about 8% for cyclists and about 82% for PTW passengers. For pedestrian children they sustained their accident while they were using a crosswalk in only 5% of the cases, and in 50% of the cases they were running across the road.

Conclusion: This paper opens the field of considering all children involved in a road traffic accident in a national safety study, not focusing only on fatal cases and not limited to the situation of children in cars. Even if some limitations due to the use of weighting factors exist, it gives a comprehensive picture of the situation in France.

Testing and Modeling of Structural Performance in Frontal Crashes

Tuesday, June 9, 2015 | 8:30 a.m.-12:30 p.m.
Chairperson: Youghan Youn, Korea | Co-Chair: Stephen Summers, United States|
TRACK B | Room: F4

PEER REVIEW PAPERNO.15-0038-O

Feasibility Study of Airbag Concept Applicable to Motorcycles without Sufficient Reaction Structure

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ABSTRACT

Research Question/Objective

An airbag system for motorcycle applications has been developed and marketed in 2006 followed by a lot of researches on the system. In the airbag system the bag should be supported during period absorbing kinetic energy of a rider in a collision. The system previously developed employed the structure that supports the bag by vehicle structures, such as a gauge unit and/or a steering handle. The supporting structure functions as a reaction structure for providing or receiving a reaction force for the airbag. However, the previous system requires a larger area for this reaction structure and is applicable only to the motorcycles that can provide that area. To overcome this limitation, here we are proposing another airbag system employing a novel concept. In this concept, the airbag does not use its vehicle structure as a reaction structure but uses the structures of an opposing vehicle, such as doors and/or pillars of a car. In this research, we aimed to verify the effectiveness of the proposing system when installed in a motorcycle that cannot provide larger area for the reaction structure.

Methods and Data Sources

In the system with this concept, it is assumed that the occupant protection performance is largely affected depending on impact configurations. Accordingly, full scale motorcycle-to-car crash tests using small scooter-type motorcycles with and without the proposing system were conducted in various impact configurations. The seven required impact configurations specified in ISO13232 were selected as the test configurations. The seven impact configurations were selected based upon their real world frequency of occurrence, or their frequency of injury to a particular body region. A small scooter-type motorcycle that cannot provide sufficient area for the reaction structure was selected as the test vehicle. All tests were conducted with Motorcyclist Anthropometric Test Device (MATD) dummy also specified in ISO13232. Injury assessment variables of head, neck, chest and abdomen, were evaluated with the MATD.

Results

Injury variables obtained from the crash tests with the airbag system were compared to those of the baseline tests. In two impact configurations, the airbag was supported by the side structures of the opposing vehicle and performed to reduce the injury variable of head and/or chest as compared to that of the baseline test.

Discussion and Limitations

It should be noted that computer simulations of the 200 impact configurations described in ISO13232 will be needed for the overall evaluation of the potential beneficial and harmful effects of the airbag system.

Conclusion and Relevance to session submitted

Through the crush tests, beneficial protection effects of the airbag system were confirmed in particular impact configurations. There was no impact configuration of significantly increased risk for the occupant due to this airbag system. It was concluded that the proposing system is feasible to reduce the occupant injuries for motorcycles without sufficient reaction surfaces. This study is relevant to the session submitted.

PAPERNO.15-0041-O

Estimation of Front Underrun Protector Effectivity in Terms of Fatalities Reduction

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ABSTRACT

Frontal collisions between cars and trucks lead to high fatality rate of the car driver. Therefore the Japanese road administration established a directive, conformity to ECE-R.93 (2000/40/EC), compulsory since September 1st, 2011. As known, this directive describes an erigid, Front Underrun Protection (FUP) device installed on a truck. New developments are in the direction of energy absorbing devices in order to manage more severe impacts between both vehicles. The question is how to estimate the effectiveness of these devices.

Using a virtual car fleet, the effect of different FUP devices installed on or integrated with a truck front end can be estimated by simulation, in terms of injury severity and crash severity. The relationship between both makes it possible to estimate injury severity via crash severity. By transferring injury severity to AIS scale and fatality rate, a coupling can be made with real accidents and their effects on injuries. The other subject is to indicate the car severity by replacing a specific car fleet to a general device, in order to simplify the evaluation. The paper shows the steps from the simulations, to the analyses and simplifications, transfer to AIS scale and mapping on the real accident database, to predict the reduction of fatalities by using different types of energy absorbing FUPs (e.a.FUP).

In order to represent the car fleet, the Moving Progressive Deformable Barrier (MPDB) was selected. The MPDB was modelled to collide to a truck with an e.a.FUP. By this method, number of fatalities, or fatality reduction rate of the car for a certain e.a.FUP was estimated from the MPDB crash severity.

The processes in this study are based on simulations and accident investigation and analysis. The vehicle models used in the simulations are mainly validated on NCAP frontal impact tests. Some cars were validated at higher speeds, up to 90 km/h.

In this paper the prediction of injury levels is only based on the HIC to show the concept/principle of the method, but the method can be extended with other injury parameters.

The method described in this paper uses the Acceleration Severity Index (ASI) of a car-to-truck frontal collision in order to determine the probability of injury and fatalities. It uses AIS scaling and mapping on a matrix of relevant car to truck accidents. This simplified method can be applied to predict the e.a.FUP effectiveness in terms of injury reduction, and especially the fatality reduction.

PAPERNO.15-0055-O

Objective Evaluation Method of Vehicle Crash Pulse Severity in Frontal New Car Assessment Program (NCAP) Tests

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ABSTRACT
In this study, the available metrics for evaluating the crash pulse severity are reviewed and their accessibility is evaluated by using the frontal New Car Assessment Program (NCAP) test data. The linear regression analysis and sled test simulations are conducted. The new approach is proposed to evaluate the full vehicle crash performance by quantifying the crash pulse severity and restraint system performance separately and objectively.

PAPERNO.15-0081-O

A Study of Gas Flow Behavior in Airbag Deployment Simulation

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ABSTRACT
Airbag deployment simulation has been utilized as an important technique to predict the occupant protection performance in the development and design stages. One of the key elements of airbag deployment behavior is the gas flow behavior of jets from inflator. In this study, in order to understand the gas flow behavior of disk type inflator for driver side airbag, visualization experiments were conducted using the schlieren method. The gas flow from the inflator with a retainer has been found to have a strong directivity. Then, the gas flow simulation was conducted with a general purpose finite element program, LS-DYNA, it was possible to obtain a good reproducibility. For reproduction, it was found that jet direction and cone angle of gas diffusion were essential elements. Next, comparison between simulation and experiments were conducted about deployment behavior of driver side airbag, the effect of gas flow on deployment behavior was analyzed. It was found from the results that the reproduction of gas flow from inflator was a major factor for reproduction on deployment behavior of driver side airbag.

PAPERNO.15-0100-O

The Force Measurement of Primary Parts in Frontal Vehicle Crash Test and those Test Methods

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ABSTRACT
In this research, the new calibration component test methodology and converted forces from strain gauge will be proposed about measuring real time force of frontal NCAP crash powertrain mounting and structure like front side member.

Key Word: Strain Gauge, Vehicle Crash, Force Calculation, Structure Force Distribution

PAPER NO. 15-0108-O

Development of the Research Oblique Moving Deformable Barrier to Better Represent Real-World Frontal Oblique Crashes

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ABSTRACT

Objective: The National Highway Traffic Safety Administration (NHTSA) has been developing a research test protocol representative of real-world injury potential in frontal offset oblique impacts. This paper will address the vehicle and occupant responses from the latest research test series.

Methods: In this series, the Oblique Moving Deformable Barrier (OMDB) impacted stationery vehicles in both left and right side impacts. Vehicles were selected only if their performance in the Insurance Institute for Highway Safety (IIHS) Small Overlap (SOI) test condition earned a "Good" or "Acceptable" rating and had side curtain air bags meeting the requirements of Federal Motor Vehicle Safety Standard (FMVSS) No. 226, Ejection Mitigation. The vehicle responses studied included total velocity change (delta-V, DV), interior intrusion and steering wheel displacement, and the occupant responses studied included Brain Injury Criterion (BrIC), Multipoint Thoracic Injury Criterion, and Ankle Moment.

Results: Generally, delta-V (DV) in the X-direction decreased as the weight of the vehicle increased in both left and right side impacts, and the interior intrusion increased toward the center of the vehicle for both impact directions as well. A significant correlation between lap belt loads and vehicle mass was not found, but there was a general decreasing trend of peak lap belt loads with increase in vehicle mass. Occupant kinematics were generally mirror images for left and right side impacts, with the occupant's head moving forward and toward the direction of impact. The near-side occupants' heads moved toward the gap between the frontal and side curtain air bags, while the far-side occupants' heads rotated off of the frontal air bag and impacted the center instrument panel.

Discussion: The Honda Accord showed the greatest difference between left and right side impact vehicle response. The highest probability of injury for both near- and far-side occupants was predicted to occur in the head, chest, and ankle, agreeing with the findings from previous real-world oblique crash injury analysis. The test mode predicted a high risk of ankle injury, primarily due to ankle inversion and/or eversion. Left and right side impacts resulted in similar magnitudes of vehicle response, but occupant responses differed enough that it may be important to consider both left and right side oblique impacts in restraint system design.

Conclusions: The interior intrusions on the toe pan increased towards vehicle center, and toe pan point TP3 consistently showed the highest intrusion measurement. Vehicle deformation from left and right side impacts can differ due to the stack up of non-symmetrical vehicle component layouts. The latest NHTSA Oblique test series involving vehicles with a "Good" or "Acceptable" rating in the IIHS SOI test condition and with side curtain air bags meeting the requirements of FMVSS No. 226 suggest that additional countermeasures may reduce injury risk in this test mode.

PAPERNO.15-0182-O

The Incidence and Severity of Small Overlap Frontal Crashes in NASS-CDS

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ABSTRACT

The Insurance Institute for Highway Safety has recently introduced a small overlap frontal crash test in its frontal rating scheme. Another small overlap frontal crash test is under development by the National Highway Traffic Safety Administration (NHTSA). Whereas the IIHS test is conducted against a fixed rigid barrier, the NHTSA test is conducted with a moving deformable barrier that overlaps 35% of the vehicle being tested and the angle between the longitudinal axis of the barrier and the longitudinal axis of the test vehicle is 15 degrees. The field relevance of the IIHS test and the NHTSA test has been the subject of papers by Prasad et al. (2014a,b). The current study is aimed at examining the combined relevance of the two tests as representing frontal corner impacts involving small overlap. The field relevance is indicated by the frequency of occurrence of real world crashes that are simulated by the test conditions, the proportion of serious-to-fatal real world injuries explained by the test conditions, and rates of serious injury to the head, chest and other body regions in the real world crashes resembling the test condition. The database examined for real world crashes is NASS-CDS. The frontal corner impacts as represented by the 25% Small overlap frontal and the NHTSA tests together address slightly less than 9% of all frontal crashes and 6% to 12% of all MAIS3+F injuries to the drivers in these crashes. The IIHS test has a somewhat higher contribution in both the incidence and severity. The two crash modes together address 4.6% to 8.2% of all MAIS3+F head injuries. Similarly, the proportion of all frontal MAIS3+F chest injuries addressed by the two crash modes or corner tests is estimated to be 6% to 10.6%.

The available data for the passenger involved in driver-side frontal corner crashes indicate that elderly female occupants predominantly experience serious head and chest injuries. All, except one, injured passengers were females. The average age of injured females who had chest injuries was slightly over 65 years. Injury rates of the head and the chest are substantially lowered in far-side than in near-side frontal impacts. Crash test ATD rotational responses of the head in the tests substantially over predict the real world risk of serious-to-fatal brain injuries.

PAPERNO.15-0183-O

A Semi-Analytical Approach to Identify Solution Spaces for Crashworthiness in Vehicle Architectures

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ABSTRACT

In an early design phase for vehicle crashworthiness, the use of classical optimization is limited. One reason for this is that development of structural components is distributed over different departments. Additionally, crash performance depends on several components and their interaction. Common components in vehicle architectures are subject to various load cases in multiple vehicles. Thus, the entire vehicle architecture has to be considered during optimization. In order to enable distributed development the system needs to be decoupled, which means that a variation in one component does not require modifications of other components in order to reach the global structural performance goal.

The objective of this paper is to introduce a method to define the component-wise force-deformation requirements of vehicle architectures for front crash structure design. The force-deformation properties of the components are subject to constraints, from which an analytical description of the design space of the vehicle architecture is derived. The

optimal orthogonal solution space within this design space is identified via optimization process. This results in maximal intervals for variations of the component forces over their deformations under the given boundary conditions. The validity of the solution space is proven through explicit FE simulation.

PAPERNO.15-0217-O

The Tracking Method of Vehicle Point or Dummy Point in the Vehicle Crash by Calculating Linear Accelerometer and Angular Velocity

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ABSTRACT
From the mathematical equations we can get the point coordinates with 3 axis linear accelerometer and 3 axis angular velocity by integration. In this research, we will introduce two unique algorithms-acceleration method and velocity method of Hyundai-Kia motors and ACTs and prove the accuracy from many kinds of dummy inboard or outboard tracking case and vehicle body point.

Key Word: Gyro, Tracking, Vehicle Crash, Dummy, accelerometer, angular velocity

PAPERNO.15-0244-O

Small Overlap Frontal Impact – Experience and Proposal for a Future Approach

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ABSTRACT
This paper examines the field relevance regarding frequency and severity of small overlap accidents by comparing accident data from GIDAS, NASS and Mercedes-Benz accident research and from this perspective shows a proposal of a more realistic small overlap test configuration. The result shows a field relevance of approx. 7% in relation to all frontal impact accidents. With respect to an occupant injury severity of MAIS3+ the field relevance is reduced to approx. 3%. Detailed investigations regarding vehicle deformations and occupant loadings on a Mercedes Benz C-Class (MJ 2013 and earlier) show significantly higher severity in the IIHS load case compared to a typically small overlap field accident. Furthermore, a better severity correlation between field accidents and a car-to-car small overlap or the NHTSA small overlap research load case has been observed. In case of the IIHS small overlap test mode some preferential vehicle concepts related to the results has been observed. Investigations show that front wheel drive vehicles with an “east-west” (lateral) engine mount design seem to have some advantage compared to rear wheel drive vehicles with a “north-south”(longitudinal) engine mount design. Accident data analysis confirms that small overlap accidents have field relevance, although the severity of the accidents is lower compared to the IIHS small overlap test mode. In order to obtain a more realistic test configuration the proposal is to use a deformable barrier in order to simulate this kind of accidents.

PAPERNO.15-0254-O

What is the Benefit of a Frontal Mobile Barrier Test Procedure?

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ABSTRACT

Frontal impact is still the most relevant impact direction in terms of injury causation amongst car occupants. Especially for car-to-car frontal impacts the mass ratio between the involved vehicles has a significant impact on the injury risk (the heavier the opponent car the higher the injury risk). In order to address this issue frontal Mobile Deformable Barrier test procedures have been developed world-wide (for example the MPDB procedure that was fully described during the FIMCAR Project). The objective of this study was to investigate how vehicles of different weight classes perform in a mobile barrier test procedure compared to a fixed barrier test procedure (the full width rigid and offset deformable barrier test). Beyond that, the influence of vehicle mass and vehicle deformation on injuries was evaluated based on real world accident data.

Five vehicle types were selected and tested in a fixed offset test procedure (ODB), a full width rigid barrier test procedure (FWRB) and a mobile offset test procedure (MPDB). For the accident analyses data from the German In-Depth Accident Study (GIDAS) was evaluated with a focus on MAIS 2+ injured belted front row car (UN-R 94 compliant cars) occupants in frontal impact accidents.

Test data indicates higher dummy loadings, in particular for the head acceleration and chest acceleration, in the MPDB test for the vehicles with a mass lighter than the trolley (1,500 kg) compared to the FWRB test. The trend of increased vehicle stiffness (especially illustrated by tests with the MPDB and small cars) shows the need of a further improvement of passive restraint systems to reduce the occupant loading and with it the injury risk.

The analyzed GIDAS data confirm the higher injury risk for occupants in cars with an accident weight of less than 1,500 kg compared to those with a crash weight above 1,500 kg in car-to-car and car-to-object or car-to-HGV, respectively. Furthermore the injury risk increases with decreasing mass ratio (i.e., the opponent car is heavier) in car-to-car accidents. Independent from the higher injury risk, the risk for passenger compartment intrusion in frontal impact appears not to be independent on the crash weight of the car.

PAPERNO.15-0343-O

A Mobile Deformable Barrier Test for the Front Crash Assessment of Future Urban Microcars

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ABSTRACT

A rising share of electric microcars (with mass well below 800kg) is predicted for the future urban vehicle fleet. Therefore the relevance of safety hazards due to mass incompatibility in case of front crashes will increase significantly. The front crash test according to ECE regulation no.94 initially defined for M class vehicles does not allow reproducing the predicted real-world crash severity for light vehicles. This paper describes an alternative test for front crash assessment of microcars using a mobile progressive deformable barrier (MPDB) with adjusted mass properties. Since the long term development of the vehicle fleet is unclear, a test set-up with parameterized barrier mass properties having the potential to reproduce variable car-to-car front crash constellations is proposed.

The relevant test parameters for a microcar front crash test are chosen based on predicted future trends from literature, expert surveys and car-to-car crash sensitivity tests. Based on that, a finite element (FE) model of a parametric MPDB is proposed, reproducing the mass properties of various possible front crash opponents. To quantify the use potential of the test, a comparison of MPDB test outputs for three types of possible microcar concepts with car-to-car crash outputs using FE Generic Car Models from the FIMCAR project as opponents is carried out. The main focus of this comparison is on structural crash performance and occupant injury. In order to bridge these two, an adequate crash restraint system triggering based on the acceleration sensing system is proposed.
As conclusion general use recommendations for the parametric MPDB test configuration are formulated.
The study presented within this document was executed within the EC co-financed project SafeEV (Safe Small Electric Vehicles through Advanced Simulation Methodologies) – www.project-safeev.eu

PAPERNO.15-0367-O

Effect of FMVSS 226 Compliant Curtain Airbags on the BrIC Result of a Hybrid III 50th% Dummy during an Oblique Impact

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ABSTRACT
The proposed oblique impact test with a Research Moving Deformable Barrier (RMDB) by the National Highway Traffic Safety Administration (NHTSA) is designed to represent crashes involving partial longitudinal structural engagement between vehicles. The RMDB moves at a speed of 56mph (90kph), with a small overlap of 35% and an impact angle of 15°, into a stationary vehicle. In addition, the newly developed Test Device for Human Occupant Restraint (THOR) dummy and the Brain Injury Criterion (BrIC) are used to evaluate the injury risk. The implementation of these test modes and measurement techniques will raise the bar for performance of passive safety systems.
Meanwhile, the introduction of the Federal Motor Vehicle Safety Standard 226 (FMVSS 226) as a countermeasure for ejection mitigation during a rollover has increased the occupant protection area of side curtain airbags (SCAB). As a result, SCAB designs have incorporated increases in height, width, and depth, depending on the interaction of the airbag with the vehicle's interior. This dimensional change in FMVSS 226 compliant SCAB, while yielding positive results in side impact and rollover crashes, may also play a critical role in the prevention of injury for the NHTSA oblique test mode. This study examines the effect of the expanded occupant protection coverage of FMVSS 226 compliant SCAB on BrIC results during an oblique impact.
This study used publicly available oblique pulse data (published by NHTSA) in a Finite Element (FE) model with a Hybrid III 50th% dummy to perform an oblique impact test. The interior environment of the FE model was obtained by digitizing a generic buck and morphing available FE models from the National Crash Analysis Center (NCAC) database. The FE model was validated with a belted 35mph frontal impact test (FMVSS 208) and then used for the oblique impact analysis. This study examines three oblique FE models, each consisting of a different configuration of restraint systems. The first configuration did not utilize a SCAB; the second configuration had a non-FMVSS 226 compliant SCAB; and the third configuration had a FMVSS 226 compliant SCAB. In order to assess the effect of SCAB design, only the upper body results of the dummy were compared and analyzed. Differences in injury response were observed between the three configurations when evaluating the head acceleration, head rotation, and chest deflection. A significant improvement was observed in the BrIC result for the FMVSS 226 compliant SCAB when compared with the other two restraint system configurations tested. Though this study is design-specific, appropriate explanations are provided to support the study.

PAPERNO.15-0257-O

Evaluation of Frontal Crash Stiffness Measures from the U.S. New Car Assessment Program

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ABSTRACT

Over the years, vehicle manufacturers may have implemented structural changes to light vehicles to comply with upgraded Federal Motor Vehicle Safety Standards (FMVSS) such as advanced air bags (FMVSS No. 208), side impact protection (FMVSS No. 214), and roof crush (FMVSS No. 216), as well as to improve performance in tests conducted by consumer information programs such as NHTSA's New Car Assessment Program (NCAP) and the Insurance Institute for Highway Safety (IIHS). Both programs have undergone changes in recent years. The NCAP was updated in 2010 to include advanced test dummies, new injury criteria, and a side pole test, and the IIHS adopted side impact, small overlap, and roof crush test protocols. Furthermore, as fuel economy requirements become more stringent, vehicle manufacturers may choose to light-weight vehicles and incorporate materials such as advanced high-strength steel and aluminum. This paper will investigate what effect, if any, these changes have had on vehicle crash pulses, as measured under NCAP. Although more stiffness metrics and crash pulse characteristics have been examined, this study mainly updates the analysis from the 2003 ESV paper, Evaluation of Stiffness Measures from the U.S. NCAP. [Swanson, 2003]

This paper utilizes data from model year (MY) 2002 to MY 2014 frontal NCAP crash tests to compute vehicle stiffness using four different methods: linear "initial" stiffness, energy equivalent stiffness, dynamic stiffness and static stiffness. The data are averaged and examined historically for three light duty vehicle classes (light duty pickup trucks (PUs), multi-purpose vehicles (MPVs), and passenger cars (PCs)) to provide a fleet perspective on changes to frontal crash characteristics. In addition, various crash pulse characteristics such as duration and peak acceleration are investigated. Collectively, these metrics have been traditionally used to characterize a vehicle's crash behavior and can subsequently influence restraint design.

The Swanson study found that not only was the average stiffness's of PCs increasing from MY 1982 to 2001, but there was also a large disparity between the average stiffnesses of PCs and those of MPVs and PUs. The current study identified different trends. The average stiffnesses of PCs and MPVs appear to be converging, indicating that these two vehicle classes may have become more structurally homogenous in this respect. This is also evidenced by the changes observed for the crash pulse characteristics. In recent years, the crash pulse durations for both PCs and MPVs have decreased (though MPVs slightly more than PCs) such that the pulse duration is now essentially equal, on average, for both vehicle classes. The average peak accelerations for PCs and MPVs also increased during the years in this study. PU data is presented for completeness, but no extensive conclusions were made on this vehicle class because no statistically significant trends could be identified.

Crash Avoidance #1: Safety Performance and Effectiveness of Driver Assistance Technologies, Test & Evaluation Procedures, Benefits Assessment

Tuesday, June 9, 2015 | 8:30 a.m.-12:30 p.m.
Chairperson: Bernie Frost, United Kingdom | Co-Chair: Anders Lie, Sweden| TRACK C | Room: F1-F2

PEER REVIEW PAPERNO.15-0050-O

The Real World Safety Potential of Connected Vehicle Technology

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ABSTRACT

Research Question/Objective

The purpose of the research detailed in this paper was to estimate the safety potential of connected vehicle technology in real world crashes.

Methods and Data Sources

Data from the Centre for Automotive Safety Research's at-scene in-depth crash investigations in South Australia were used to simulate the circumstances of real world crashes. A total of 97 crashes that represented the most prevalent crash types for injury or fatal crashes, and had potential to be mitigated by connected vehicle technology, were selected for inclusion in the study. The trajectory, speeds, braking and impact configuration of the selected in-depth cases were replicated in a software package and converted to a KML file format to appear as if they had come from a GPS unit in each of the involved vehicles. The crash circumstances were then replayed on two Cohda Wireless on board units connected by a cable link. The Cohda Wireless on board units are a mature connected vehicle technology that has been used in the US DOT's Safety Pilot project, and have been tuned for low false alarm rates when used in the real world. The time at which the Cohda Wireless unit issued an audible warning was used to calculate a new impact speed using three different reaction scenarios and two levels of braking.

Results

It was found that between 57 and 86% of the simulated crashes could be avoided if the braking level was 0.7g and between 37% and 60% if the braking level was only 0.4g, with highest percentage due a fully autonomous system and the lowest when a human reaction time of 1.2s was assumed. A fully autonomous system that was braking at 0.7g also reduced the impact speed relative to the actual crash in all cases. Even when a human reaction time of 1.2s and moderate braking of 0.4g was assumed the impact speed was reduced in 78% of the crashes. Crash types that proved difficult for the threat detection engine were head on crashes where the approach angle was low and 'right turn-opposite' crashes.

Discussion and Limitations

Limitations of the approach used are that the radio communication environment was not simulated, no other sensor data was used (e.g. CAN data), and the position fix was 'perfect'. Furthermore, the driver reaction times were assumed

using accepted human reaction times, only the viewpoint of the striking vehicle was considered and joint avoidance was not considered. The crash types that proved difficult for the connected vehicle technology could be better addressed if CAN information is available, such as steering wheel angle, so that driver intent can be inferred sooner. More accurate positioning in the real world would allow the technology to be more effective for head on crashes, while still minimising false alarms.

Conclusion and Relevance to session submitted

These results indicate that connected vehicle technology can be greatly beneficial in real world crash scenarios. This benefit would be maximised by having the vehicle intervene autonomously with heavy braking.

PAPERNO.15-0370-O

A Comprehensive and Harmonized Method for Assessing the Effectiveness of Advanced Driver Assistance Systems by Virtual Simulation: The P.E.A.R.S. Initiative

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ABSTRACT

The assessment of real-world effectiveness of advanced driver assistance systems (ADAS) is gaining importance as more and more systems enter the market. Many different approaches have been developed. Therefore, the automobile industry, universities, and automotive research institutes in Europe have started an initiative for cooperative research. A 'Harmonization Group' was established in 2012 whose motivation is the development of a comprehensive, reliable, transparent, and thus accepted methodology for quantitative assessment of these systems by virtual simulation.

The harmonization group focuses on prospective analysis, which has the objective to estimate the expected safety benefits of current and beyond-state-of-the-art applications. Commonly used methods for prospective analyses are FOT's, subject studies in driving simulators, on closed test tracks or on open roads, and virtual analyses by means of simulation. Currently, the basis for an assessment by virtual simulation can be obtained either from reconstructed real-world crashes or from generic synthetic scenarios derived from realistic distributions of pre-crash conditions and traffic. Simulations allow for large number of cases and thus are capable of fulfilling the requirements posed by a sound sample size calculation. Simulation is certainly not a sole generic solution for all kinds of research questions, but it represents an

integrative method to combine different knowledge areas in order to achieve an overall effectiveness result. It offers a promising combination of speed, flexibility, reproducibility, and experimental control.
The expected outputs of the group activities are the following:

- Identification of research questions (e.g. what changes in traffic safety can be expected due to the introduction of system X in country Y?);
- Definitions and metrics of the effectiveness (e.g. % reduction in fatal/injury crashes in a specific country/Europe; total reduction in fatalities over a period depending on a penetration rate);
- Structure for the assessment procedures including a description of the required sub-processes and the procedures to be followed;
- Description of the basic abstract models that are used in the simulation: driver, vehicle, road, traffic, and safety systems. The driver model is used to simulate various driver responses to inputs from the environment and the signals of the ADAS in various driving situations, traffic conditions, cars, and environments;
- Examples of the assessment of several ADAS (e.g. Lane Departure Warning, Advanced Cruise Control, Automated Emergency Braking).

The paper is a methodological paper presenting on-going activities of the Harmonization Group, so-called P.E.A.R.S. (Prospective Effectiveness Assessment for Road Safety), that involves more than 30 institutions in Europe. Applied results will come once the harmonized framework is completed and the validation tests on several driving assistance systems have been shown successful. Further the document is set up to deliver the appropriate input for a draft proposal of an ISO or SAE standard.
This activity is an opportunity to harmonize methodologies used for assessment of ADAS in Europe. The involvement of non-European based stakeholders allows for a worldwide harmonization impact. A comprehensive assessment theoretical framework as well as concrete techniques should become available for wide usage by all stakeholders involved in ADAS effectiveness assessment.

PAPERNO.15-0063-O

A Survey of Electrical and Electronic (E/E) Notifications for Motor Vehicles

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ABSTRACT
Modern motor vehicles are becoming increasingly dominated by electrical and electronics (E/E) systems. While this trend is clear, its implications are uncertain. In this paper, we investigate data on safety-related notifications from the United States, Canada, and Europe to analyze questions and trends related to E/E systems. The data analysis indicates that E/E systems are a growing issue for motor vehicle safety, and that the time delay for E/E notifications is longer than that for other notifications, and that specific subsystems are more prone to E/E problems than others.

PAPERNO.15-0268-O

Automated Generation of Virtual Driving Scenarios from Test Drive Data

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ABSTRACT
Intelligent vehicle systems such as ADAS, ITS and automated driving systems consist of increasing numbers of sensor technologies as well as increasingly advanced algorithms for sensor fusion, object tracking, object classification, risk estimation, driver status recognition and vehicle control. It is rapidly becoming infeasible to check the performance of each new (sensor) system in the traditional way: By performing test drives, storing data, manually labelling the data for reference, and manually evaluating the results. One of the approaches to address these difficulties is to install a

reference sensor system on the test vehicle in addition to the prototype sensor system (device under test). The recorded data from the reference sensor system are processed – partly or fully - automatically to create reference scenarios, based on automatic object labelling and automatic event identification. Based on these reference data, the device under test can be automatically and objectively evaluated. The reference data from the reference sensor system can now be converted into a set of virtual scenarios which can be used within a CAE environment. These simulated "ground-truth reference scenarios" offer a platform for engineers to quickly check the consequences of design changes to the device under test, and allow engineers to subject the device under test to a wide variation of virtual traffic scenarios.

PAPERNO.15-0283-O

Tools and Methods for Current and Future Controllability Assessment

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ABSTRACT

Driver related evaluation of Advanced Driver Assistance Systems (ADAS) needs to address controllability, effectiveness and user acceptance, which are to some extend interfering with each other. The state of the art in the controllability assessment is currently defined by the Code of Practice of the RESPONSE 3 project which focuses on the driver-system-interaction with single assistance functions like ACC or LKA. However, the controllability evaluation of new assistance functionalities such as ADAS of automation level 2 or automated driving on level 3 (according to SAE definitions) requires a review of the existing methods and tools with regard to necessary adaptations and new developments.

For controllability evaluation of future ADAS and systems of higher automation levels the existing methodology needs to be adapted. Aspects to be considered in this context are the increasing amount of information with regards to the automation level. This information needs to be perceived and processed by the driver when interacting with multiple parallel operating assistance functions and complex information and communication systems.

The controllability of urban assistance functions and their failures is subject of discussion especially focusing on tools and methods for an urban controllability assessment. To that end, driving simulator experiments, vehicle-in-the-loop and real vehicle studies are conducted analyzing existing controllability methods on their suitability for urban assistance functions. The results show the specific advantages of each applied testing tools and suggest that an overall system evaluation addressing controllability, effectiveness and acceptance combines the advantages of the different testing environments.

Next to acceptance and effectiveness the controllability analysis is embedded in the overall evaluation process with focus on the driver and the interaction with the vehicle. The controllability analysis process for higher levels of automation is described. An overview of state of the art controllability evaluation is provided. The problem for future systems is analyzed and possible methods and tools are proposed. The necessary methods and tools are described focusing on next generation ADAS and higher levels of automated driving.

The results are limited to the driver interaction with assisted driving. For the assessment of the driver reaction to higher automation levels the use of a high-fidelity driving simulator seems reasonable to achieve a high reproducibility of the driving scenario and a good representation of the driving dynamics.

PAPERNO.15-0139-O

Effectivity Analysis and Virtual Design of Integrated Safety Systems

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ABSTRACT

Design, optimization, and assessment of integrated safety systems (combining active and passive elements) pose considerable challenges. For example, the spectrum of potential situations in the field in which active elements might be triggered is considerably larger than one can achieve under controlled testing conditions.

In this context, it is crucial to evaluate quantitative metrics relating as closely as possible to human risks and benefits, such as avoidance of injuries or reduction of injury severity. The consequences of unnecessary interventions and other side effects on passengers or traffic also need to be quantified. This paper describes a generic approach to assessment of field effectiveness and evaluation of active and integrated safety systems. The approach, based on virtual experiments, is holistic, in that both active and passive safety elements are evaluated using a common metric while seeking the most effective solutions regarding overall improvement of vehicle safety. The complexity of process models and their interactions utilizes an advanced knowledge base. In order to achieve this goal, the whole sequence of events in a hazardous situation is virtually implemented in a tool chain. The tool chain includes stochastic (or "Monte-Carlo") traffic simulation, generating large samples of accident sequences but also near-misses, as well as detailed, high-resolution crash simulations of resulting accidents. The methods are useful not only for assessment of existing integrated safety designs, but also for comparing different system concepts or optimizing performance within a complex design concept. The potential of this approach is illustrated for several key accident scenarios.

PAPERNO.15-0211-O

Bicyclist Behavior Analysis for PCS (Pre-Collision System) Based on Naturalistic Driving

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ABSTRACT

In recent years, automakers have introduced the PCS (Pre-Collision System) which is designed to warn a driver or to brake automatically to help avoid or mitigate accidents. One of the significant aspects of this system is to help protect vulnerable road users such as pedestrians and bicyclists. In this paper, the research is introduced which analyzes normal bicyclist behavior in order to design and evaluate PCS systems. The attributes of normal bicyclist behavior investigated are: TTC (Time-To-Collision), lateral position, vehicle speed and bicycle speed. This behavior was analyzed using TASI's (IUPUI's Transportation Active Safety Institute) naturalistic driving data from 110 cars.

PAPERNO.15-0097-O

Real-Time Pedestrian & Driver Analysis by Neuromorphic Visual Information Processing

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ABSTRACT

Objective

The safety enhancement of road users has begun to gain more attention, in particular the innovation and application of ADAS. The accurate and timely detection of the risk of accident has become an active area of research, with the focus on the drivers and other vulnerable road users.

The neuromorphic visual information processing method, inspired by Hubel and Wieselį¯s experiments on mammalian visual cortex, is proposed as a possible solution to these tasks. The proposed method replicates the performance of visual cortex in practical computing settings. By applying the orientation feature extraction and subsequently applying the neural network ensured robustness and accuracy.

Method

The proposed system has been evaluated on pedestrians/cyclists detection and driver monitoring, with a particular focus on emotion/stress detection. The tests have been carried out with video data sets of various conditions, with the experimentation and data set generation at public roads in every day settings.

The neuromorphic visual monitoring of drivers for the attentive or emotional status has been also evaluated, as approximately 15% of road accidents have been caused by the dangerous driving in į®anger and or/frustrationį¯. The driver monitoring system by detecting the emotional state from the limited facial image of driver would make the measures of early warning against possible dangerous or inattentive driving. The neuromorphic system was evaluated to determine the warning signal based on the emotional state detection, based on the key feature extracted from the face images. The test was based on the facial database (JAFFE) of six basic emotional states.

Results and Conclusion

The performances of neuromorphic visual information system were measured to the success rate 99% of pedestrian/cyclist detection, and the successful recognition 91% of facial emotional states. The real-time performance was evaluated with the neuromorphic ASIC, fabricated by the automotive CMOS technology. The processing speed of neuromorphic ASIC alone was tested for the speed of 30 frames per second, without the latency or external memory.

PEER REVIEW: PAPERNO.15-0040-O

Fast Calculating Surrogate Models for Leg and Head Impact in Vehicle-Pedestrian Collision Simulations

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ABSTRACT

Research Question/Objective

Vehicle-pedestrian accidents still remain a serious problem due to their disproportionately high contribution to traffic fatalities and injuries. Therefore measures to reduce these fatality and injury numbers have to be taken. The effectiveness of such safety measures can be estimated prospectively by numeric simulation of a large number of relevant and possibly critical traffic situations.

A common method to do this is using impact-speed based injury risk curves for effectiveness assessment of a certain safety measure. However this only works for impact-speed reducing measures and since the relation between impact-speed and injury risk is based on retrospective analyzes, current or specific vehicle's properties (e.g. geometry and stiffness) cannot be considered.
In previous research, a tool-chain to simulate vehicle-pedestrian accidents from ordinary driving state to in-crash has been developed. It consists of a pre-crash-simulation, a multi-body-system (MBS) simulation for determination of head impact and a detailed finite-element-analysis (FEA) model including vehicle front and head and leg impactor for calculation of commonly accepted injury criteria values (e.g. head injury criterion/HIC15). This toolchain therefore allows for injury criteria based, vehicle specific (geometry, stiffness, active safety systems etc.) assessments. Due to the complex nature of the FEA models, calculation times are very high. This is a major drawback for using FEA models in large-scale effectiveness assessment studies. Therefore fast calculating surrogate models to approximate the relevant injury criteria as a function of pedestrian vehicle collision constellations have to be developed.

Methods and Data Sources
We present the development of surrogate models for head and leg injury criteria to overcome the problem of long calculation times while preserving high detail level of results. These surrogate models are then used in the toolchain as time-efficient replacements for the FEA model to approximate the injury criteria values. The method consists of the following steps: Selection of suitable training datasets out of a big number of given collision constellations, detailed FEA calculations with the training datasets as input, training of the surrogate models with the FEA model's in- and output values.

Results
A separate surrogate model is created for each injury criterion, consisting of a response surface which maps the input parameters (i.e. leg impactor position and velocity) to the output value. We also present a performance test comparing surrogate model predictions of additional collision constellations to the results of respective FEA calculations.

Discussion and Limitations
The developed method allows for good prediction of injury criteria based on impact constellation for a given vehicle. Since the surrogate models are specific to a certain vehicle, training has to be redone for a new vehicle. Still there is a large benefit regarding calculation time when doing large-scale studies.

Conclusion and Relevance to session submitted
The method can be used in prospective effectiveness assessment studies and takes into account specific local features of a vehicle (geometry, stiffness etc.) as well as external parameters (location and velocity of pedestrian impact). Furthermore, it can be easily extended to other injury criteria or accident scenarios.

PAPERNO.15-0098-O

Evaluation of The Effectiveness of Volvo’s Pedestrian Detection System Based on Selected Real-Life Fatal Pedestrian Accidents

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ABSTRACT

The objective of this work is to test freely available system for active pedestrian protection. Tests are based on real fatal accidents that happened in the past with passenger cars that were not equipped with active safety systems. Tests have been conducted in order to evaluate what the real benefit of the active safety system is, and not to gain only a methodological prediction. The testing procedure was the first independent testing in the world which was based on real fatal pedestrian accidents. The aim of the tests is to evaluate the effectiveness of Volvo pedestrian detection system.

An in-depth accident database contains about 300 fatal pedestrian traffic accidents in urban areas. Eighteen cases of pedestrians hit by the front end of the passenger vehicle were extracted from this database. Cases covering an average traffic scenario have been reconstructed to obtain detailed model situations for testing. Simulations of accidents have been made in PC Crash 10.0 using a multibody object and a mesh model of vehicles. Active safety testing scenario was built on the basis of reconstructed accidents with Volvo V40 cc and a new dummy simulating a pedestrian. Before the tests the dummy was evaluated in anechoic room to gain required radar reflection properties which would be the same as those of a human body. The movement of the dummy was driven by the autonomous ultraflat overrunable robot (UFO) for experimental ADAS testing and synchronized with Volvo motion by D-GPS with high accuracy of motion.

PAPER NO. 15-0354-O

Aspects of Age Related Accident Causation Factors and Implication for Safety Measures

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ABSTRACT

Research Question/Objective

The ageing society increases the requirements to focus on safe mobility for elderlies. It is expected that in Germany the population with an age above 65 years will reach more than 30% of the total population by 2060. In the same time the number of people above 80 years will double. In addition the relative share of driving license holder amongst the elderly will increase. In order to maintain the active role in mobility it is essential to identify specific risk factors of elderly and to develop countermeasures. The objective of this paper is to analyse specific accidents causes of elderly car drivers and to assess different measures such as improvement of the infrastructure, training measures, driver assistance systems etc.

Methods and Data Sources

For this study accident data of the Accident Research Unit Hannover (part of the GIDAS data sample) were used. The analysis focuses on the detailed 3 digit accident type and the Accident Causation Analysis System (ACAS) to identify functional problems in traffic situations with high accident risk for elderly. The driving task is derived from the detailed accident type, which describes the conflict that caused the accident and in more detail the positions and intended directions of the opponents.

ACAS as a hierarchic classification system and a sequence model is based on an in-depth data collection of predominantly directly event-related causation factors which were crucial in the accident emergence as situational resulting events and influences. The paradigm underlying this method refers to the findings of the psychological traffic accident research that most causally relevant features of the system components human, infrastructure and vehicle technology are found directly in the situation shortly before the accident. The focus in the immediate pre-crash phase lies on the human failures which are classified into five categories of basic human

functions which are necessary to perform the driving task. With the detailed knowledge of the causes of the accident the causation factors are further specified into criteria of the categories and indicators of these criteria.

Results
The analyzed data shows that there are considerable age related deficits in the assessment of multiple information, e.g., reorientation after entering a crossing, observation of road users approaching from bypasses (e.g., cyclists) etc. Most of these deficits can be compensated by improved infrastructure, specific training modules and driver assistance systems. Predominantly information systems and active assistance systems for elderly drivers with the driving task "turning in intersections" can be useful.

Discussion and Limitations
Due to a limited number of elderly car drivers with ACAS codes in the GIDAS data set for most of the scenarios the number of cases is too low to analyse the data without grouping similar accident types and using main categories of the ACAS code. However, the data is consistent with knowledge from literature.

Conclusion and Relevance to session submitted
The paper presents data that judges which safety measures (mainly focusing on driver assistance systems) are beneficial for elderly car drivers on the one hand and describes relevant scenarios for the assessment of these safety measures on the other hand.

PAPER NO. 15-0212-O

Road Departure Protection - A Means for Increasing Driving Safety Beyond Road Limits

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ABSTRACT
Despite great technical progress in vehicle safety, according to the WHO approximately 1.2 million fatalities occur on the world's roads every year. Thus great efforts are undertaken to reduce the number of road fatalities and serious accidents, or at least to mitigate their impact on road users. The introduction of environment perception based Advanced Driver Assistance Systems (ADAS) in road vehicles is expected to improve traffic safety significantly. In today's vehicles, the prevalent ADAS focus primarily on the longitudinal driving direction, e.g. Autonomous Emergency Braking (AEB) systems and Adaptive Cruise Control. Whilst the functional range of these systems continues to expand, there exists a very large portion of critical vehicle crashes which are not addressed, mainly caused by vehicles leaving the roadway laterally.

Today, Electronic Stability Control (ESC) is one of the only established Active Safety Systems covering emergency situations in the lateral direction, and always dealing within the physical limits of vehicle dynamics. Despite the very high effectiveness of ESC systems, there remain many cases in which it is not possible to prevent unintended lateral roadway departures, especially in cases of driver drowsiness or inattention, e.g. on American highways or European rural roads. Preventing roadway departure crashes, which cannot be covered by today's lateral guidance/lane keeping ADAS, is motivation behind developing a system for road departure protection. Road Departure Protection systems expand today's lateral ADAS by active road keeping in emergency situations before reaching the physical limits of vehicle

dynamics. Based on environment perception means like road edge detection or road course preview, the system should actively intervene when unintentionally leaving the roadway. By automated vehicle control, the system keeps the vehicle on the roadway, thereby protecting against roll-over accidents or collisions with roadside obstacles or oncoming traffic.

This paper presents the roadway departure problem we face today via accident data and different use cases and gives insight into the state of the art Active Safety functions and research activities. The functionalities to address the selected use cases will be described, including functional architectures, a road edge detection algorithm, approaches to preview the course of the road, sensor fusion concepts, a function cascade, and activation strategies. First test data will illustrate the function and working area of a Road Departure Protection system.
A reliable and real-time capable perception algorithm will be demonstrated. For this algorithm, different image processing techniques are applied to mono camera images to estimate the parameters of a geometric model of the road edge. It works without any supplementary knowledge about the road infrastructure.
Two system architectures will be presented, which differ in the used surrounding sensors, actuators, functional capabilities, and system cost. One variant uses a radar sensor, stereo camera and an Electric Power Steering (EPS) system, whereas another solution uses a mono camera and an ESC system. The vehicle steering capabilities and limitations of the ESC based steering are discussed in the paper. Finally, an outlook to future work and possible extensions will be given.

PAPERNO.15-0222-O

Research on Driver Acceptance of LDA (Lane Departure Alert) System

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ABSTRACT
The purpose of this research is to identify whether the road departure accident reduction performance of the Lane Departure Alert (LDA) system is consistent with driver acceptance. If a vehicle deviates from the lane, the LDA system warns the driver and/or automatically steers the vehicle back into the lane to help avoid an accident. However, the system cannot perform as expected if the driver feels that the system is annoying and turns it off. Therefore, the consistency between the accident reduction performance and driver acceptance of LDA was studied by investigating driving behavior based on a new form of two-dimensional analysis using the distance to the lane boundary (DTLB) and the lateral velocity of the vehicle.

PAPERNO.15-0080-O

Potential Safety Benefits of Lane Departure Warning and Prevention Systems in the U.S. Vehicle Fleet

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ABSTRACT
Road departures account for nearly one-third of all fatal crashes. Lane departure warning (LDW) and lane departure prevention (LDP) have the potential to mitigate the number of crashes and fatalities that result from road departure crashes. The objective of this study was to predict the effectiveness of LDW and LDP in preventing road departure crashes if all vehicles in departure crashes in the U.S. fleet were equipped with either system. A set of 478 road departure crashes extracted from NASS/CDS 2012 were used to formulate a simulation case set. Each of these crashes were than simulated with and without LDW and LDP systems. The LDW system was assumed to alert the driver at the

instance the leading wheel touched the lane marking. A steering-based LDP system was assumed to operate in conjunction with LDW (i.e. by alerting the driver of a lane departure) and directly modulate steering wheel angle at the instance the leading wheel touched the lane marking. Four hypothetical LDP designs were evaluated, using typical evasive maneuvering behavior from a lane departure, to be representative of “light”, “moderate”, “aggressive”, and “autonomous” steering. The LDW system was estimated to reduce the number of crashes by 26.1% and the number of seriously injured drivers by 20.7%. In contrast, the light steering to aggressive steering LDP systems were estimated to reduce the number of crashes by 32.7% to 37.3% and the number of seriously injured drivers by 26.1% to 31.2%. The LDP system with autonomous driving characteristics were estimated to reduce the number of crashes by 51.0% and the number of serious injuries by 45.9%. This study shows that LDW and LDP could mitigate a large proportion of crashes and injuries in lane departure crashes. This paper is directly relevant to the design and evaluation of LDW and LDP systems.

PAPER NO. 15-0176-O

Evaluation of a Pre-Production Head-On Crash Avoidance Assist System Using an Extended "Safety Impact Methodology" (SIM)

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ABSTRACT

Objective: This paper describes the results of the Honda-DRI ACAT-II program initiated by the National Highway Traffic Safety Administration (NHTSA) to develop test and evaluation procedures and methods to assess the safety benefits and effectiveness of advanced driver assistance technologies. The objectives of the ACAT-II program were further development of a formalized Safety Impact Methodology (SIM) for estimating the capability of advanced technology applications installed in vehicles to address specific types of motor vehicle crashes, and to evaluate driver acceptance of the technologies.

Methods: This particular ACAT study extended earlier work by Honda and DRI in the NHTSA ACAT-I program by extending the SIM so as to be able to analyze head-on crashes more completely, and by using the extended SIM to evaluate of a pre-production version of a Honda Head-on Crash Avoidance Assist System (H-CAAS). More than 25 substantial SIM extensions and refinements were implemented, including: updated and extended FARS and NASS database extractions; improving the accident reconstruction process for NASS/CDS cases and developing a new special purpose reconstruction algorithm applicable to head-on cases with low lateral acceleration “drifts;” extending the driver-vehicle-ACAT-environment simulation to include a post-conflict recovery phase; and further automating the overall safety benefits evaluation steps. The extended SIM and results from objective tests were used to evaluate the safety impact of Honda’s pre-production H-CAAS based on a large number of simulations of a sample of reconstructed real-world head-on crashes.

Results: The effectiveness of the H-CAAS in reducing the number of two-vehicle “Same Trafficway, Opposite Direction” crashes (including non-H-CAAS technology relevant crashes) and fatalities if the H-CAAS were installed on one of the crash involved vehicles were estimated to be a 2.6% reduction in these types of crashes and a corresponding 11.3% reduction in fatalities based on simulation results. The overall benefits of the H-CAAS, in terms of reduction in number of crashes and fatalities, when projected to the annual US level were estimated to be a 2,966 reduction in the number of US crashes and a corresponding reduction of 450 US fatalities per year. The results are based on various assumptions, approximations, and limitations that are summarized herein and further documented in the supporting references, such as the representativeness and accuracy of the supporting data and reconstructed accident pre-crash scenarios.

Conclusions: Overall, this ACAT-II program was successful in extending and demonstrating a methodology that can be used to estimate the effectiveness and safety benefits and driver acceptance of frontal crash avoidance and mitigation countermeasures. The methods used are directly relevant to the test and evaluation procedures to assess the safety benefits and effectiveness of advanced driver assistance technologies.

Biomechanics #1: Development, Validation and Use of Human Body Models in Assessment of Crash Injury

Tuesday, June 9, 2015 | 2:00 p.m.-6:00 p.m.
Chairperson: Matthew Craig, United States | Co-Chair: Rainer Hoffmann, Germany| TRACK A | Room: F3

PAPERNO.15-0312-O

Abdominal Characterization Test under Lap Belt Loading

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ABSTRACT
The phenomenon of submarining is of major interest in the design and optimization of restraint systems. A biofidelic finite element human body model can be more useful for investigating this phenomenon than the existing dummy. For the validation of finite element human body models, belt pull tests were performed to characterize thoracic and abdominal regions of the PMHS, and the 50%tile male Hybrid III dummy was tested for comparison with the PMHS. The spines of subjects were rigidly mounted to a test fixture through a mounting system to minimize the influence of the spinal motion during the test. The pelvis of the subjects were positioned close to the normal driving posture, but the torso angle was more reclined than the average driving posture due to the difficulty of adjusting the torso angle during the mounting process. This torso angle led to the belt being positioned more rearward with respect to anterior superior iliac spine (ASIS) in the longitudinal direction. The subjects were loaded under lap belt only configurations with two levels of load limits, 1 kN and 3 kN. The lap belt was positioned in various vertical offsets with respect to ASIS and belt angles. The vertical offset of the belt from ASIS was determined based on volunteer test data. Belt pulling distance, belt cable force, spine reaction force, and belt kinematics were documented for the human body model validation. During the lap belt tests, both belt sliding over the pelvis and belt staying in front of the pelvis were observed, and a large amount of abdominal compression was observed during the submarining cases. After finishing the test series, autopsies were performed on the PMHS, and both PMHS showed no injuries in the abdominal region. One of the PMHS also showed a pelvic fracture at the iliac crest, but the PMHS had a pre-existing healed pelvic fracture at the same location. It was believed that this pre-existing fracture had not healed completely prior to death. Note that its ASIS region was intact so it should not have affected the occurrence of the submarining-like belt kinematics. Although only two PMHS were tested, the biomechanical responses collected through the belt pull test can be used to validate the computational human body model for further investigation on the submarining phenomenon.

PEER REVIEW: PAPERNO.15-0165-O

Age and Sex-Specific Thorax Finite Element Model Development and Simulation

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ABSTRACT
Research Question/Objective
The shape, size, bone density, and cortical thickness of the thoracic skeleton vary significantly with age and sex which can affect the injury tolerance especially in at risk populations such the elderly. Computational modeling has emerged as

a powerful and versatile tool to assess injury risk and improve the effectiveness of vehicle safety systems. However, current computational models only represent certain ages and sexes in the population. The purpose of this study was to morph an existing finite element (FE) model of the thorax to depict thorax morphology for males and females of ages 0-100 and to investigate the effect on injury risk.

Methods and Data Sources

Age and sex-specific FE models were developed using thin-plate spline interpolation. In order to execute the thin-plate spline interpolation, homologous landmarks on the reference, target, and FE model are required. An image segmentation and registration algorithm was used to collect homologous rib and sternum landmark data from males and females aged 0-100 years. The Generalized Procrustes Analysis (GPA) was applied to the homologous landmark data to quantify age and sex-specific size and shape changes, as well as isolated shape changes in the thorax. The Global Human Body Models Consortium (GHBMC) 50th percentile male occupant model was chosen as the reference mesh. The GHBMC model was morphed to create age and sex-specific thoracic shape change models (scaled to a 50th percentile male size). To evaluate the thoracic response, two loading cases (frontal hub impact and lateral impact) were simulated to assess the importance of geometric, material property, and cortical thickness changes with age and sex.

Results

Due to the geometrical changes with age and sex, there were observed differences in the response of the thorax in both the frontal and lateral impacts. In the frontal rigid hub impact, a 30 year old male produced a peak force of 4.43 kN with a maximum deflection of 33.23% while a 70 year old male produced a peak force of 4.37 kN with a maximum deflection of 31.12%. Due to the increase of the horizontally angling of the ribs relative to the spine with age, the older models have stiffer thoracic responses. Incorporation of material property and cortical thickness changes with age and sex demonstrated decreases in thoracic stiffness which resulted in an increased risk of rib fracture with age.

Discussion and Limitations

The results of the 180 FE simulations are consistent with the findings in literature. The age and sex-specific models developed in this study incorporate detailed changes in geometric, material property, and cortical thickness changes based on a large population sample.

Conclusion and Relevance to session submitted

Current FE models are limited to certain ages and sexes in the population. In this study, age and sex-specific thoracic models were developed and the biomechanical response was studied using frontal and lateral impact simulations. The development of these age and sex-specific FE models of the thorax will lead to an improved understanding of the complex relationship between thoracic geometry, age, sex, and injury risk.

PEER REVIEW: PAPERNO.15-0166-O

Age dependent factors affecting thoracic response: a finite element study focused on Japanese elderly size occupants

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ABSTRACT

Research Question/Objective

Elderly comprise half of the traffic related fatalities in Japan, being male drivers at the highest risk. Within this group, thoracic injuries account for the majority of the fatalities; likely due to non-optimized restraint systems for thoracic fragility of aged in general, and reduced size of Japanese elderly in particular.

Our ultimate goal is to reduce thoracic injuries due to traffic crashes, especially in elderly. The specific objective is to develop and validate a finite element (FE) model of an average Japanese elderly male size that accounts for relevant age factors that can support the deployment of elderly-specific thoracic safety countermeasures.

Methods and Data Sources
A new thoracic FE model was developed from medical images of a Japanese elderly size (71 years old, 161cm, 60Kg) cadaver. The model was validated at component and assembled (table top) levels against original series of test data obtained from the same elderly specimen and previously published.
The model was completed with extremities and head of a model (JAMA) previously developed. Age properties of the ribcage and the thoracic flesh were implemented. Thereafter, the model was verified against controlled belt loading data, pendulum impact age-specific corridors and frontal sled test corridors from literature and simulation parametric studies were conducted to understand the effect of each factor on thoracic response. Besides age properties, body size effect was also analyzed by adding simulations with an AM50 version of the model.

Results
In tabletop test conditions, the model behaved according to experiments in intact, denuded and eviscerated tissue conditions, and predicted fracture location and timing at which the only bi-cortical fracture occurred in the experiments. When age parameters were analyzed, in descending order, muscle softening, rib cortical thinning, rib cortical fragility and costal cartilage fragility due to ageing affected thoracic stiffness.
In frontal sled conditions, the elderly size model showed less forward motion than M50 corridors, as expected from its reduced body mass and height. The M50 size model showed good three dimensional head and spine kinematics, as well as ribcage multipoint deflections. Age properties only did not affect head and spine kinematics but did increase severity of ribcage deformation modes and predicted number of rib fractures.

Discussion and Limitations
The thoracic FE model was developed from one elderly specimen and validated against experiments on the same specimen. The ribcage geometry was representative of the targeted population. However, uncertainties of the geometry of the elderly specimen with respect to the specimens used to develop the experimental corridors for model verification remain.
The resulting effect of age factors such as rib cortical thickness and properties are similar to comparable literature. Aged, flesh softening, reduced coupling effect of the ribcage in compressive and lateral directions. Aged costal cartilage increased the bulging out of the lower right ribcage (right shoulder engaged) typically observed in frontal sled experiments.

Conclusion and Relevance to session submitted
Under simulated standard experimental conditions, age-specific parameters affected thoracic injury risk without affecting overall body kinematics. After size effects were isolated, we identified two new age factors, costal cartilage and flesh, that affect ribcage deformation mechanisms and increase associated rib fracture risk.

PAPERNO.15-0313-O

Rib Length Variation with Age and Sex - Measurements from High-Resolution Low-Radiation X-ray Images of Volunteer Subjects

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ABSTRACT
Research Question: Human surrogates such as anthropomorphic test devices and computational models are common tools used by the automotive industry to characterize injury mechanisms and design countermeasures. The surrogates currently available were designed to be representative of certain sex and percentile of the population, such as the 5th- and 50th-percentile females, and the 50th- and 95th-percentile males. Great improvements were achieved in crash protection thanks to these models, but there is a need for more refined models that take into account a greater variation of the human diversity, such as the geometric variation due to aging. Therefore, the objective of this study was to determine how the length of ribs varies with age and sex.

Methods and Data Sources: A total of 103 asymptomatic volunteer subjects aged 0 to 84 years old were included in the study. First, each volunteer was imaged either with a standard clinical CT-scan, or in a standing position with the EOS imaging system, a low-radiation X-ray system that acquired one frontal and one sagittal high resolution images of the ribcage. Second, a custom-made software toolbox was used to create a subject-specific geometrical 3D model of each subject bony ribcage by registration of a statistical parametric ribcage model. Third, the rib length and mean thoracic index were extracted from the 3D ribcage models.
Results: The two main results were that the thoracic index (depth to width ratio of the thorax) was found to be fairly age-independent, and that the ribs length increased linearly with age between 0 and 20 years old before reaching a plateau. The growth rate of the ribs increased between each rib level from rib 1 (4 mm/year) to rib 10 (10.5 mm/year). This indicates a change in the size and shape of the ribcage during growth.

Conclusion and relevance: The study provides a quantitative characterization of age and sex-induced variation in the ribcage geometry, based on asymptomatic adult volunteer data. This study addresses the need for the geometric data required to build a set of computational models that represent male and female subjects of various age.

PAPERNO.15-0387-O

Unveiling the Structural Response of the Ribcage: Contribution of the Intercostal Muscles to the Thoracic Mechanical Response

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ABSTRACT
Current finite element (FE) models of the human body do not properly include the contribution of the intercostal muscles (ICM), which is believed to limit their rib fracture prediction capabilities. In the present study, an existing full body model for a seated 50th-percentile male was evaluated under five cases of loading: point loading of the denuded ribcage, frontal pendulum impact tests, lateral and oblique pendulum impact tests and table top tests. The sensitivity of the model to changes in material model of the ICM was evaluated by using two material models: an isotropic linear elastic material model and a foam model defined by a single uniaxial load curve extracted from a recent literature. The performance of these models compared to the experiments was assessed quantitatively through a correlation analysis on the force and chest deflection time histories. The simulations found that that the material properties of the ICM have little effect on the externally measured impact force and chest deformation except in point loading.

PAPERNO.15-0373-O

Implementation of New Rib Material Models to a FE - Human Body Model for Evaluation of the PRE-SAFE Impulse Side Restraint System for Side Impact Protection

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ABSTRACT
“Integrated“, “Smart“, and “Individual”, are new characteristics of future safety systems. Furthermore, side crashes are still dominant in terms of high injury risk for car occupants and are predicted to become even more relevant in future. Earlier studies on pre-conditioning the occupant during pre-crash phase have shown the potential to reduce injury risk in such accident scenarios. To evaluate and optimize such advanced safety systems to provide a high safety level for the occupant, finite element human body models were used Especially integrated safety systems which interact with the occupant in the pre-crash phase require these new

and supplementary evaluation tools.
With specific focus on the use case, the thorax and rib material of the FE human body model THUMS-D were modified and validated. Two different rib material properties have been defined for two different age groups, one for the young population and one for the elder population based on quasi static and dynamic 3-point bending test setup. Furthermore, a damage model for the rib fracture was created and implemented to the THUMS-D model. The validation process of the complete thorax followed pendulum impact standards set by GESAC 2005 and ISO/TR 9790:1999.
Finally the PRE-SAFE Impulse Side system was evaluated and optimized applying this upgraded THUMS-D model in FE car crash environment.

PEER REVIEW: PAPERNO.15-0148-O

Effect of Age on Brain Injury Distribution in Rotational Head Trauma - A Parameter Study Using a Rat Finite Element Model

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ABSTRACT

Research Question/Objective

Traumatic brain injuries (TBI) due to traffic accidents remain a worldwide issue. Children and elderly are at higher risk; this is likely due to lower brain tissue stiffness for younger and brain shrinkage for older persons. However, the effect of these changes on the injury outcome is still unknown and requires clarification. The aim of this study is to clarify the effect of age related intracranial changes on the outcome of Diffuse Axonal Injuries (DAI) under rotational head loading.

Methods and Data Sources

A simulation based parametric study was conducted using a validated finite element model of the rat head and brain. Two age-dependent factors: brain atrophy and region specific brain material properties, were implemented in the model. The model was subjected to both injurious and non-injurious sagittal plane rotational acceleration levels. Brain cortex sliding with respect to the skull and tissue strain measures in different brain regions were extracted from the simulations and compared to an original set of experimental data in which groups of young and older rats were subjected to rotational trauma

Results

The simulation results showed that brain cortex sliding relative skull bone correlate with experimental measurements and are dependent on both loading conditions and material properties. Sliding between the brain and the skull increased with age, as measured using the Relative Motion Damage Measure criterion, suggesting a potentially increased risk of acute subdural hematoma. Both age-dependent factors considered had significant effect on the potential outcome of DAI as indicated by Cumulative Strain Damage Measures. Finally, brain tissue strain patterns at maximum loading show that the highest strains are concentrated in regions around the border between corpus callosum and cortex. When older material properties were included, spread of strains towards lower and more posterior brain regions occurred, which is consistent with the experimental observations. These results are consistent with those of a comparable parametric study conducted with a human FE model and clinical data.

Discussion and Limitations

The most important limitations of this study apply to most state-of-the-art animal and human brain FE models. First, there is a lack of literature on experimental data for brain tissue material properties for short duration loading events such as those simulated in this study. Second, non-linear effects in the brain tissue material model utilized were not

implemented. The latter will likely provide an underestimation of the stiffness (and overestimation of strains) when compared to non-linear models.

Conclusion and Relevance to session submitted
This study provides valuable information on the effect of age related parameters that may contribute to different injury outcome observed in age-grouped rat experiments. Such information will guide future experimental studies in rotational head trauma and provides guidance concerning the parameters that need to be considered when developing age specific brain FE models. In the mid and long term, we expect this knowledge to improve the understanding of age effects on injury outcome, which will be crucial to take age-specific effective preventive countermeasures for TBI injury reduction.

PEER REVIEW: PAPERNO.15-0102-O

Sensitivity of Head and Cervical-Spine Injuries to Impact Parameters Relevant to Rollover Crashes

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ABSTRACT

Research Question/Objective
Serious head and cervical-spine injuries have been shown to occur mostly independently of one another in pure rollover crashes. In an attempt to define a dynamic rollover crash test protocol that can replicate serious injuries to the head and spine it is important to understand the conditions that are likely to produce serious injuries to these two regions. The objective of this research is to analyse the effect that impact factors relevant to a rollover crash have on the injury metrics of the head and cervical spine, with a specific interest in the differentiation between independent injuries and those that are predicted to occur concomitantly.

Methods and Data Sources
A series of head impacts was simulated using a detailed finite element model of the human body, the Total HUman Model for Safety (THUMS), in which the impactor velocity profile, contact surface, and impact direction were varied. The performance of the THUMS was assessed against available experimental tests performed under comparable conditions. Indirect, kinematic-based, and direct, tissue-level, injury metrics were used to assess the likelihood of serious injury to the head and cervical-spine. The locations of predicted bony and soft-tissue injuries were identified for comparison with real-world injury data from Australian and US databases.

Results
Preliminary results indicate that the velocity profile and direction of impact had the greatest effect on injury risk for the cervical-spine and head, respectively. In general, serious head and cervical-spine injuries were predicted occur independently of each other. Concomitant head and cervical-spine injuries were predicted to occur primarily at greater impact velocities.

Discussion and Limitations
Although serious injury thresholds for the head and cervical-spine have not been firmly established for finite elements models, the trends of direct and indirect injury metrics can be useful in indicating the conditions that are more or less likely to produce a serious injury. The independent occurrence of predicted head and cervical-spine injuries indicates that it may not be feasible to replicate both head and spine injuries in a given dynamic rollover test. The results of this study may be useful in reconstructing the position of an occupant's head and neck, with respect to the contact surface, at the time of injury in field crashes.

Conclusion and Relevance to session submitted

The trends in predicted head and cervical-spine injury severity were analysed for a range of head-impact conditions. Serious head and cervical-spine injuries were generally predicted to occur independently of each other. The relevance of this paper to the session lies in its application of a parametric analysis, using the finite element method, to increase understanding of head and cervical-spine injuries in impacts relevant to rollover crashes.

PEER REVIEW: PAPERNO.15-0157-O

Development and Validation of the Total HUman Model for Safety (THUMS) toward further Understanding of Occupant Injury Mechanisms in Pre- and Post-Crashes

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ABSTRACT

Research Question/Objective

The active safety devices such as automatic emergency brake (AEB) and pre-crash seatbelt have the potential to accomplish further reduction in the number of the fatalities due to automotive accidents. However, their effectiveness should be investigated by more accurate estimations of their interaction with human bodies. In this decade, many researchers developed computer simulation models of the human body with a variety of modeling approaches including multi-body method or finite element (FE) method as well as simplified structure or detailed one in human body anatomy. However, each modeling approach has advantages and disadvantages in computational costs and injury predictions. The objective of this study is to develop and validate a human body FE model, which can be used for multiple injury predictions in whole body with the relatively low computational costs.

Methods and Data Sources

In this study, we developed a human body FE model called THUMS (Total HUman Model for Safety) with a body size of AM50. The model has anatomical structure of bones, ligaments, muscles, brain, and internal organs. The total number of elements is about 274,700, which would realize the relatively low computational costs. Deformable material models were assigned to all body parts. The bones were modeled as isotropic elasto-plastic material with failure strains. The muscle-tendon complexes were modeled by bar elements with the Hill-type muscle material and seatbelt material to reproduce the moment arms of some muscles. The material properties of the tissues were obtained from the literature (Yamada 1970). The human model was firstly used for verification of each body part (Kitagawa et al.1998, Rupp et al.2008, Wismans et al.1987, etc.). The model was then validated against several whole body cadaver test data of frontal, lateral, and rear impacts (Vezin et al.2001, Cavanaugh et al.1993, Ono et al.1997). The human model with a vehicle sled model (NCAC/JSOL) was secondly applied to investigate effects of muscle activation in the pre-crash phase with the AEB on injury outcomes in frontal impacts.

Results

In the verifications and the validations of the developed human model, force-displacement, force-time, displacement-time curves, predicted by the model showed good or acceptable agreement with those of cadaver test data in all cases. In the investigation of muscular effects, the braced occupant decreased the displacement of the upper body and then decreased injury outcomes in head and thoracic regions.

Discussion and Limitations

Since the developed human model has all deformable body parts and the detailed structure of the brain and internal organs as well as the ability of muscle activation, the model has a possibility for total evaluation of whole body injuries with and without muscle activation. However, the model has the limitations on insufficient validation of active muscle model using volunteer test data.

Conclusion and Relevance to session submitted
The developed model has the potential for multiple injury prediction in whole body with the relatively low computational costs. This title is appropriate for Session: Biomechanics #1: Development, Validation and Use of Human Body Models in Assessment of Crash Injury.

PEER REVIEW: PAPERNO.15-0115-O

Development of a Computationally Efficient Human Body Finite Element Mode

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ABSTRACT

Research Question/Objective
The goal of this study is to develop a simplified and computationally efficient human body finite element model. This model complements the Global Human Body Models Consortium (GHBMC) full detailed 50th percentile occupant by providing kinematic and kinetic data with a significantly reduced run time, using the same body habitus.

Methods and Data Sources
The simplified occupant model (M50-S) was developed using the same source geometry as the GHBMC 50th percentile male seated occupant model v4.2 (M50). While some meshed components were preserved, the total element count was reduced by remodeling muscles and thoracoabdominal organs as homogeneous components utilizing a majority hexahedral mesh. The brain was replaced with a point mass at the CG of the rigid skull. The surface mesh of all bones, except the ribcage for biofidelity considerations, was preserved from the M50 model but modeled as rigid bodies. Material models for all deformable components were drawn from the biomechanics literature. A rapid model positioning system was implemented via kinematic joints which are used to represent the articulations of the body.

Results
The M50-S model has 9 contacts and 345 thousand elements, 202k of which are rigid and 143k deformable; compared to the M50 model with 447 contacts and 2.1 million elements. Three rigid body biomechanics impacts and three vehicle simulations were completed to compare the kinematic and kinetic response of the M50-S to the M50 and cadaveric responses. In a frontal rigid hub impact simulation the M50-S produced a peak force of 4.6 kN and a maximum deflection of 28.8%, with a run-time of 13 minutes using a 48 core cluster. In contrast, the M50 produced a similar peak force and deflection of 4.9 kN and 30.1% respectively, but with a 10 hour run-time. Results from a 150 millisecond frontal sled impact (Shaw et al.) demonstrated analogous kinematics and reaction forces to the experimental results. At 150 milliseconds, the vertical displacement of the head varied by less than 4 centimeters from the experimental mean. For both impacts, the simplified model completed the simulations roughly 50 times faster than its detailed counterpart.

Discussion and Limitations
As Finite Element Models of the human body become more complex, a tradeoff exists between biofidelity and computational cost. While certain anatomical features are omitted and local injury prediction capacity is removed, the simplified model provides numerous benefits. The model can be re-positioned rapidly, it provides a potentially more biofidelic alternative to ATD models due to its anatomically based structure, and can be used in parametric studies. Finally, because it has the same body habitus as the M50 model, in future studies, components of the detailed M50 can be inserted within the M50-S for regional biomechanics studies.

Conclusion and Relevance to session submitted
A simplified model with the same body habitus as the GHBMC 50th percentile seated occupant model was developed for computational efficiency and ease of positioning. The results demonstrate that the model compares favorably with the detailed model and cadaveric studies while substantially reducing computational cost.

PAPERNO.15-0247-O

Aiming for an Average Female Virtual Human Body Model for Seat Performance Assessment in Rear-End Impacts

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ABSTRACT

The female part of the population suffers more Whiplash Associated Disorders (WAD) in car crashes than males. Several studies have illustrated the need to consider the female population when developing and assessing the WAD prevention performance of advanced restraint systems in rear-end collisions. Presently only one crash test dummy is available, the average sized male BioRID. Recently a virtual dummy model of an average female, EvaRID, was developed and used in rear impact simulations. The results stressed the need for models representing the female part of the population, as well. Virtual crash simulations have become essential in traffic safety and with models of both an average male and female, further steps in addressing improved assessment of WAD prevention can be taken. The present paper presents a starting point of research aiming to develop an open-source average female Finite Element (FE) model with an anatomically detailed cervical spine. This paper provides a review of the literature to identify gender specific neck biomechanics and anatomical differences, followed by a review of published FE models of the cervical spine.

Data on vertebral body dimensions (height, width, depth, spinal canal diameter, facet joint angles) have been compiled from biomechanical literature. Significant gender differences exist for the vertebral body depth and width, the spinal curvature in the seated posture, and the spinal stiffness and range of motion. All have the potential to influence the outcome of an impact and should be accounted for in the development of WAD prevention.

The review of FE models of the cervical spine presented 17 models based on male geometry but only one model scaled to represent a female. An overview of the models were given, with respect to the solver, geometry source, number of elements, and implementation of the facet joints, ligaments, and muscles. It is recommended that an average female model is developed with focus on; 1) the shape of the female vertebral body, especially the depth and width that provides less support area than for males, 2) defining the spinal curvature representative of seated female volunteers who generally display less lordosis than males, 3) the dimensions of the spinal ligaments, rather than the material properties, to capture the larger range of motion and less spinal stiffness of female subjects compared to males, and 4) validation to female volunteers and PMHS tests for range of motion, while failure prediction seem less gender sensitive.

PAPERNO.15-0345-O

Muscle Activation Strategies in Human Body Models for the Development of Integrated Safety

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ABSTRACT

Human Body Models (HBMs) have been used in crash safety research for some time, and are now emerging as tools for the development of restraints systems. One important challenge in the development of advanced restraint systems is to integrate sensory information about the pre-crash phase (time to collision, impact speed and direction, occupant position) to alter restraint activation parameters. Restraint activation can begin even before the beginning of an impact, providing additional time to reposition or restrain the occupant. However, any such pre-crash intervention would invoke a muscle response that needs to be taken into account in HBMs used in simulation of integrated restraints.

The objective of this paper is to provide an update on state-of-the-art modeling techniques for active musculature in HBMs. Examples of applications are presented, to illustrate future challenges in modeling of car occupants muscle responses to restraint activation.

The most common approach for modeling active muscle force in HBMs is to use Hill-type models, in which the force produced is a function of muscle length, shortening velocity, and activation level. Active musculature was first implemented in cervical spine models. These models were applied to study occupant kinematic responses and injury outcome in rear-end, lateral, and frontal impacts; it was found that active musculature is essential for studying the response of the cervical spine. One approach utilized to represent muscle activity in HBMs is to use experimentally recorded muscle activities or activity levels acquired through inverse optimization in open-loop. More recently, in order to represent car occupant muscle responses in pre-crash situations, closed-loop control has been implemented for multibody and finite element HBMs, allowing the models to maintain their posture and simulate reflexive responses. Studies with these models showed that in addition to feedback control, anticipatory postural responses needs to be included to represent driver actions such as voluntary braking.

Current HBMs have the capacity to model (utilizing closed-loop control) active muscle responses of car occupants in longitudinal pre-crash events. However, models have only been validated for limited sets of data since as high quality volunteer data, although it exists, is scarce. Omni-directional muscle responses have been implemented to some extent, but biofidelity of the simulated muscle activation schemes has not been assessed. Additional experimental volunteer muscle activity measurements (with normalized electromyogram recordings) in complex 3D-loading scenarios are needed for validation and to investigate how muscle recruitment depends on occupant awareness and varies between individuals. Further model development and validation of muscle activations schemes are necessary, for instance startle responses, and individual muscle control. This could improve assessment of restraint performance in complex accident scenarios, such as multiple impacts, far-side impacts and roll-over situations.

Testing and Modeling of Structural Performance in Side Impact and Rollover Crashes

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Tuesday, June 9, 2015 | 2:00 p.m.-6:00 p.m.
Chairperson: Bengt Pipkorn, Sweden | Co-Chair: Mark Terrell, Australia| TRACK B | Room: F4

PAPERNO.15-0068-O

Simulation and testing of Adaptive FRP-Substructures for Automotive Safety

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ABSTRACT

This paper describes the development of a basic finite element simulation model of a concept for an adaptive structure made with carbon fiber reinforced plastic materials. Thereby in particular the prediction of the mechanical properties of necessary deformation zones in the structure, that are realized with an elastomer matrix system, is challenging due to the different properties of this material compared to conventional composites. Available material models in the FE-Code LS-DYNA are analyzed for their usability in this task. For the parameterization of the material models a number of coupon tests are conducted and the deviations between the material with the elastomer matrix and the material with the conventional duromer matrix system are analyzed. The results of these tests are used to validate the material models for both, the material used in the expansion zone and the conventional composite material in the rest of the structure. It is shown that the prediction of the shear properties of the elastomer based material creates difficulties with the used material model (MAT_54) but in total the correlation between test and simulation is good and comparable for both materials.

The first task that has to be approved for an adaptive structure made of FRP-materials is the expansion-process from the initial to the pressurized final geometry. For this purpose a quasistatic inflation test is performed. The results of the test and a corresponding simulation correlate well for the pressure at which the expansion of the structure begins. Regarding the maximum burst pressure and the location of the material failure deviations between test and simulation occur. Possible reasons for this deviation are analyzed and discussed.

Finally the additional necessary steps in the creation of a predictive simulation model for an adaptive FRP structure under crash-load and possible approaches for the latter are discussed.

PAPERNO.15-0135-O

Robust Design Method for Automotive and Aerospace Composite Structures Including Manufacturing Variations

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ABSTRACT

Objective

Composites may enable further weight reductions for plastic composite intensive vehicles. Among the challenges associated with greater adoption of composites in the automotive industry are the need for novel design procedures, the use of composites in impact applications and the greater variability during composite manufacture. Here, are method is presented to account for composite manufacturing variability in the design phase.

Methods

The method is based on measuring the variability in a part and the translation into a simulation. As an example a side-pole impact into a doorsill subassembly was chosen. The test data are used to validate numerical simulations models for the impact situation. The simulation is then used to study the sensitivity of the system with respect to manufacturing variability. A novel optimization was also used that decouples multiple manufacturing variations and allows identifying limits on acceptable variability levels.

Results

The experimental tests exhibit changes in mechanical performance due to the existence of manufacturing variations. The numerical simulation including these manufacturing variations shows reasonable agreement with the experimental data. The FE model was then used to vary the manufacturing variations and to identify allowable intervals within defined performance criteria.

Conclusion

The design methodology has significant benefits for automotive composite design and manufacturing since it may enhance the robustness of composite crash-structures, reduce part cost and eliminate excessive safety factors to account for unknown manufacturing variations.

PAPERNO.15-0105-O

The Force Measurement of Primary Parts in Vehicle Side/Small Overlap Crash

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ABSTRACT

In this research, the new calibration component test methodology and converted forces from strain gauge will be proposed about measuring real time force of side structure like B-pillar, roof rail, door beams and side sill of IIHS side crash and lower arm, A-pillar force of IIHS smalloverlap.

PAPERNO.15-0209-O

Load Transfer of Passenger Car Compartment for Improvement of Structural Performance in Side Impact

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ABSTRACT

We demonstrate the effectiveness of a new method for expressing the load transfer in passenger car bodies to improve structural performance in order to protect occupants in side impact. For vehicle structures, one of the most important goals is the reduction of compartment deformation. For this purpose, indicating the load transfer paths in a vehicle compartment is fundamentally significant. The present authors previously developed an index Ustar (U*) to express the load paths in structures. Our purpose in the present study is to express the load transfer using U* in a vehicle compartment in side impact.

The index U* is defined as U* = 1 □|U/U□ when an arbitrary point is constrained. We can say that U* shows the connectivity between the loading point and an arbitrary point. It is natural to think that the force is transferred along the highest part of the U* distribution. The index U* can realize a way to obtain the overall view of load transfer in the vehicle compartment during collisions.

We introduce the extended U* in which the effect of inertial force is included for the calculation of vehicle collision. The calculated distribution of U* for a sample passenger car shows that the impact force is transferred mainly to the lower structure of the compartment. However, the load is not transferred to the opposite body side, because of the separation caused by the center tunnel structure. The U* distribution shows that among the several transverse cross-members, the cross-member under the B-pillar plays a key role in load transfer. In contrast, the cross-member under the front seat has a small effect for load transfer. These results of load transfer are demonstrated by the colored U* contour lines in the entire compartment for any specified instant during impact. The calculated results are expected to improve the side impact crashworthiness to reduce the risk of injury to occupants.

As an example, to increase the load transfer of the cross-member under the front seat, we locate the stiffener member between the side sill and the tunnel structure. The designation of the stiffener location is pinpointed by the distribution of U*. A crash simulation of a sample vehicle equipped with the stiffened cross-member reveals that the side sill intrusion deformation decreases by more than 30%. The value of the decrease rate itself is not a key point of the result. The point of importance is the effectiveness of the deduction process by U* for the strict determination of structural improvement.

PAPERNO.15-0363-O

Development of High Efficiency Load Path Structure to Enhance Side Impact Safety Performance

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ABSTRACT

In order to protect the occupants effectively in side impact crashes, the main tasks are (a) to minimize the intrusion of the deformed body structure after the impact in order to reduce direct contact force with the occupant and (b) to reduce the relative impact velocity of the intruding structure at the start of contact with the occupant. The existing concepts similar to SIPS (Side Impact Protection) system are basically based on good structural integrity with seat-mounted side air bags and roof-mounted curtain air bags for overall protection of the occupant in side impact crashes. However, for higher level of external input load at an inclined angle from high front-end SUVs acting on the side of an ordinary PV in case of SUV-to-PV side impact crashes, there is a room to have more efficient structural load-path system layout. A new inclined L-shaped High Efficiency Load Path System (HELPS) was developed and incorporated at the back of the existing seat back frame to bypass a part of the incoming load to the central console through the seatback frame.

At first, a number of full vehicle FE-simulation studies were carried out to verify the performance in IIHS and SINCAP tests to assure the effectiveness of the concept. Finally, it is tuned to a feasible optimized structure in order to ensure other functional aspects, such as, seating comfort of the front passenger, leg-room of the rear occupants, etc. Its performance was calculated assuming various seating positions of the frontal occupant to examine the robustness of the concept in real world safety. Human Body Model (HBM) simulations were also carried out to compare two systems, one with HELPS and the other without HELPS concept. Similar to the results of the dummy response in IIHS and SINCAP tests, reductions inoccupant injury level were observed in HBM simulations.

PEER REVIEW: PAPERNO.15-0034-O

Potential of a pre-crash lateral occupant movement in side collisions of (electric) mini cars

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ABSTRACT

Research Question/Objective

In the collaborative research project VisioM the partners Technische Universität München, Daimler AG and Autoliv have developed a concept of lateral seat-movement as a countermeasure for side impact.
There are more and more electric mini cars in the European market technically classed as heavy quadricycles (L7e) which have the look and feel of small city cars (e.g. smart fortwo). Euro NCAP recently tested vehicles of this class in front and side impacts, all of which showed critical safety problems.
In these mini cars the survival space between side structure and occupant is reduced even more compared to conventional vehicles for side impacts. Occupant loads due to side impacts can be reduced via lateral pre-acceleration of the occupant. This is carried out by lateral seat-movement in the precrash phase. Thus, greater intrusion is allowed as well as a reduced due to the pre-accelerated occupant.
The objective is to find the optimal seat-movement characteristics, which leads to minimal occupant loads.

Methods and Data Sources

The Euro NCAP side collision is simulated in LS-Dyna with a finite element model consisting of VisioM body-in-white, VisioM seat, VisioM restraint system, ES2 dummy and ECE-R95 barrier.
The optimal parameters of the restraint system and of the precrash movement are found using surrogate-based optimization methods by maximizing the Euro NCAP score. Parameters are the time-to-fire of the head-airbag, pelvis-thorax-airbag and the pretensioner, several shapes of the airbags, the inflator performance of the airbags and different seat-movement characteristics (change in velocity and distance). The lateral movable distance of the seat is limited to 100 mm. The precrash time window in which the seat can be moved is limited to 150 ms before time to collision.
The optimized parameters are validated with several verification runs as well as a full vehicle crash test with the VisioM prototype.

Results

The simulations show a significant reduction in occupant loads due to the precrash seat-movement. Compared to a tuned restraint system without, the score improves by 15 % with seat-movement. Generally, the greater the allowed displacement of the seat, the lower the occupant loads. During the seat-movement, occupant loads stay in an uncritical range. The usage of a seatbelt pretensioner helps to have a better coupling of the occupant to the seat.

Discussion and Limitations

The seat-movement is only possible if there is enough space for the movement. Adaption to different occupant weights can be done by changing the time-to-fire of the seat.
The movement of the occupant with the VisioM seat worked well, yet a better formed seat would couple the occupant

even more.
Though the used dummy has no muscles and therefore could react differently to occupants in the precrash phase during seat-movement, former conducted tests with humans and the ES2 dummy show a similar behavior in the first 150 ms of the precrash phase.

Conclusion and Relevance to session submitted
The vehicle based countermeasure seat-movement offers better occupant protection in side impacts for (electric) mini cars.

PAPERNO.15-0131-O

Analysis of Vehicle Roof Weakness and Potential for Neck Injuries from Experimental and Simulated Dynamic Rollover Tests

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ABSTRACT
Despite the considerable rollover crashworthiness research carried out to date, there is still a need to establish exactly how spine and neck injuries occur to a seat-belted occupant during a rollover. This paper details an experimental and Finite Element (FE) analysis aimed at demonstrating how a stronger vehicle roof can reduce the potential for neck injuries to a seat belted occupant seated in the front on the rollover far-side.
An analysis was carried out of the head-torso kinematics of a seat-belted Anthropomorphic Test Device (ATD) measured during two rollover crash tests conducted on a weak- and strong-roof sport utility vehicle (SUV), respectively. Both experimental laboratory rollover tests were performed under the same nominal conditions using the original Center for Injury Research (CFIR) Jordan Rollover System (JRS) located in Goleta, California. Further, a comparison of the ATD kinematics was then carried out using data obtained from detailed FE simulations of vehicle rollovers carried out using the FE model of the University of New South Wales (UNSW) JRS located in Sydney Australia, and an FE model of a SUV, first with the original production roof and then with a reinforced roof.
The analysis of the experimental tests indicated that an excessive roof crush would likely cause the head to be captured within the crush zone long enough for the torso to apply a large inertial axial-compression load to the neck. In contrast, a stronger roof continuously guides the occupant's head moving it along an arc in a smoother manner, thus reducing any significant change in velocity between the head and torso, and any consequent inertial axial-compression loading. However, preliminary computer simulations confirm this mechanism only in part, and further simulations of the refined computer model of the UNSW JRS and SUV models are being conducted and will be reported on when completed.

PAPERNO.15-0145-O

Association between Vehicle Panel Damage and Thoracic Injury in Rollover Crashes

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ABSTRACT
Rollover crashes are infrequent and account for approximately 2% to 3% of all vehicle crashes in the US annually. However, when they do occur they are more likely to result in a serious injury or fatality than some other types of crashes. In rollovers, the thorax has been identified as one of the three most frequently seriously injured body regions.

As such, research has been carried out over the last few decades to understand better environmental, vehicle and occupant variables in a rollover crash which contribute to an occupant sustaining a serious, i.e. of severity greater than or equal to three on the Abbreviated Injury Scale (AIS 3+), thoracic injury. The findings from the research described in this paper will provide information for the development of a dynamic rollover crash test protocol which includes assessment of thoracic injuries. The aim of this study is to determine if there is an association between vehicle panel damage and AIS3+ thoracic injuries. NASS CDS data from 2001 to 2012 was examined for single vehicle rollover crashes with occupants receiving serious thoracic injuries (cases) and those without thoracic injuries (controls). Vehicle panel damage for both cases and controls were coded and logistic regression performed to determine if there is an association between serious thoracic injury and vehicle panel damage.

The result of this study indicates that there is an association between thoracic injury and damage to the top-half of the left front door, top-half of the right front door and left side of the vehicle rearwards of the B-pillar.

PAPERNO.15-0336-O

Dynamic Validation of Rollover Buck Roof Structure

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ABSTRACT

Effective passive countermeasure design for rollover injury prevention requires thorough understanding of the occupant response in rollover impact. Thus, the dummy biofidelity in rollover crashes is important. To evaluate the dummy biofidelity a test buck was developed for a variety of surrogate biofidelity analyses. The buck was designed to mimic the geometry and inertial properties of a modern strong-roof vehicle. It consisted of two major parts: a deformable, replaceable greenhouse and a rigid base. The goal of this study was to show that the greenhouse structure proposed in this paper, when loaded in a static roof crush test (similar to FMVSS 216) reaches the strength-to-weight ratio level of real vehicles and when loaded in a dynamic rollover test, the roof deformation matches deformation magnitude and shapes observed in the vehicles from the current United States (US) fleet. To achieve this goal a multi-step design approach was used, including a quasi-static roof crush test and a rollover test on fabricated prototypes of the buck roof structure. Based on the gathered data, modifications were introduced to the roof design to improve the greenhouse mechanical response, both dynamically and quasi-statically. Once the design was fixed, one additional static and twelve dynamic rollover tests were performed and roof structure deformation was compared to the measurements made on two late-model US-market vehicles (an SUV and a mini-van), tested in similar conditions. The roof exhibited a desired response under the quasi-static loading with the peak value (61.1 kN) within first 127 mm of platen motion, which resulted in the strength-to-weight ratio of 3.76. During the twelve rollover tests the magnitude and shape of the buck roof deformation were consistent with those measured on the two test vehicles. In the twelve tests the maximum resultant displacements of the trailing side A- and B-pillar (after excluding three outlier tests due to welding defects) were as follows: 189-223 mm and 183-222 mm, respectively. The component displacements of the B-pillar were: between 165-198 mm in SAE Y and between 84-106 mm in SAE Z. The results of this study showed that the designed roof structure can match the deformation magnitude and shapes, including the prevalence of greater lateral than vertical displacement, seen in the current US fleet vehicles. The roof developed in this study has a quasi-static response similar to that of real vehicles loaded in a FMVSS 216-like test. It mimics the stiffness of real vehicle roofs under static and dynamic roof crush loading, and thus it can be used with the test buck to simulate real vehicle rollover crashes to perform parametric analyses and evaluate dummy biofidelity.

PAPERNO.15-0350-O

The Effect of Road Contact Angle and Pitchyaw Angle on the Injury of Drivers in Cris Test

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ABSTRACT

This paper shows the effect of the roof contact angle with ground and pitch/yaw angle on head and neck injuries in CRIS tests. In this study the effect of these conditions on injury in a rollover is simulated and analyzed by using a commercial multi-body software (ADAMS). The vehicle model consists of a rigid lower body and deformable upper body. Each member of the upper body is characterized to get the similar behavior to the results obtained from an equivalent finite element model. To evaluate the severity of driver¡¯s injuries in a CRIS test, a computer simulation to replicate the dynamic CRIS test is developed. The angular velocity of vehicle is set to a constant value of 270 degree/sec and the lateral velocity is varied to be 28.8kph or 35kph so that it can roll 2 or 3 turns. The roof contact angle with ground is selected to be 135, 145 and 155 degrees. The pitch and yaw angles of the vehicle is also varied to be 2 or 5 degrees and 0, 10, or 20 degrees, respectively. In addition to the peak acceleration of the dummy head, the maximum shear force, compressive force, and bending moment acting on the dummy neck are calculated to evaluate the rollover safety for various conditions. The simulation results are then compared to the KNCAP evaluation criteria. Considering the fact that the rollover accidents with less than 2 full turns account for about 90% of the entire rollover accidents, this study suggests that the 2-turn condition would be appropriate for a protocol of the dynamic rollover test.

PAPERNO.15-0359-O

Fighting Driver Distraction – Recent Developments 2013 - 2015

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ABSTRACT

Research on driver distraction has a long history and attracts the attention of the scientific community, the public and the authorities. This resulted in a great number of activities. This article will summarize the main developments since the last ESV in 2013 from the perspective of an automotive manufacturer.

Guidelines and standards: In 2013 the National Highway Transport and Safety Agency (NHTSA) published a guideline for visual manual HMI. While basically following the structure of the European Statement of Principles (ESoP) [2] and the AAM guideline [1], the NHTSA guideline is much more restrictive, which means that more functions need to be blocked while driving. So the concern is that drivers will be inclined to use nomadic devices which have no restrictions at all (i.e. smartphones). Thus the overall impact of that guideline on safety may be negative.
The last version of the ESoP was published in 2008. In the framework of the iMobility Forum an HMI group was installed with the objective to check whether any changes, updates or additions are needed. The final report is expected for 2015. Some statements can be expected from the current draft which contains some recommendations and explicitly states to keep the ESoP as a design guideline, based on ISO standards, but not to include overall acceptance criteria. Due to the growing importance of applications that are being developed independently from hardware, another group was established within iMobility Forum, SafeAPP, in order to cover this specific topic.
On international level OICA (Organisation Internationale des Constructeurs d'Automobiles) published a white paper with recommendations for guidelines.

Naturalistic driving studies (NDS): Most experiments in simulators or on test tracks measure driving performance or glance behavior to determine mental workload. For using the telephone they usually report an odd ratio of four (The probability of a crash is four times higher compared to normal driving). It was quite a surprise when the 100 car study in 2013 presented odd ratios below one. Recent data from SHRP 2 give even lower values. NDS seem to be a powerful tool to identify actions and behavior that cause crashes. Detailed methods are under development and handling of great amounts of data is a challenging task.

Tethering: Nomadic devices can cause a problem since neither their displays nor their controls are developed for automotive use. Also they do not block functions that are not intended to be used while driving. One way to overcome this problem is to tether the telephone with the display and the controls of the car. This also makes it possible to apply existing guidelines (AAM, JAMA, ESoP). The Car Connectivity Consortium (CCC) has rephrased the existing guidelines so that they are better understandable by app developers. The CCC also established a process that will be run by certified labs to verify that the applications are in line with the guidelines.
Similar approaches are done be Google (Android auto) and Apple (Car play).

PAPERNO.15-0240-O

Repeatability of the NHTSA Visual-Manual Guidelines Assessment Procedure

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ABSTRACT

The Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices includes the Eye Glance Measurement Using Driving Simulator Testing (EGDS) task acceptance test. This paper describes the outcome of two EGDS tests, where both tests assessed the same set of 10 in-vehicle tasks, though each test employed a different group of 24 test participants, randomly sampled according to the proscribed EGDS procedure. Thus, in total 48 test participants drove on a simulated motorway in a lead vehicle following scenario while performing tasks such as changing temperature, setting destination in the navigation system and selecting and playing music using a prototype in-vehicle infotainment system located on the center panel. When comparing the test outcomes between the two groups, it was found that for 6 of the 10 tested tasks, pass/fail outcomes differed between the two groups on one or more of the proposed criteria. This high level of inconsistency in outcome between two identical tests using ten identical tasks raises questions regarding the repeatability of the proposed NHTSA EGDS procedure.

PEER REVIEW: PAPERNO.15-0057-O

Using Sound to Reduce Visual Distraction from In-Vehicle Human-Machine Interfaces

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ABSTRACT

Research Question/Objective

Driver distraction and inattention is the main cause of accidents today. The fact that devices such as navigation displays and media players are part of the distraction problem has led to the implementation of guidelines all over the world advocating various means of minimizing the visual distraction from such interfaces. However, although design guidelines and recommendations are followed, certain interface interactions, such as menu browsing, can still require a lot of visual attention. In this paper we investigate if adding sound to an in-vehicle user interface can provide the support necessary to create a significant reduction of glances towards a display when browsing menus.

Methods and Data Sources

Two sound concepts were developed and studied; Spearcons (Time-compressed speech sounds) and Earcons (Musical sounds). A simulator study was conducted in which 14 participants between ages 36-59 took part. Participants performed 6 different tasks in two different visual displays, one placed next to the speedometer and the other in the center stack, while driving along a highway route. A 3x6 within-groups factorial design was employed with Sound (No sound /Earcons/Spearcons) and Task (6 different task types) as factors. Eye glances and corresponding measures were recorded using a head-mounted eye tracker. Participants' self-assessed driving performance was also collected after each task with a 10-grade scale ranging from 1= very bad to 10= very good. Separate ANOVAs were conducted for different eye glance measures and self-rated driving performance.

Results

It was found that the added Spearcon sounds significantly reduced Total Glance Time as well as Total Number of Glances while retaining task time as compared to the Baseline (= no sound) condition (Total glance time M = 4.15 for Spearcons vs. M= 7.56 for Baseline, $p<.01$). The Earcon sounds did not result in such distraction-reducing effects. Furthermore, participants ratings of their driving performance was also statistically significantly higher in the Spearcon conditions compared to the Baseline and Earcon conditions (M= 7.08 vs. M= 6.05 and M= 5.99 respectively, $p< .01$).

Discussion and Limitations

As can be seen, the Spearcon sounds seem to offer a very efficient way of reducing visual distraction. While the Earcon sounds did not reduce distraction measures or increase the subjective driving performance it is still believed, based on the comments given by the participants, that such sounds can be used to inform about depth-wise position in a menu. It should be noted that the participants had very little training with the sounds prior to the experiment so it is expected that glances towards displays can be reduced more or even avoided completely with additional experience. Nonetheless, an aspect that must be further investigated is how well this type of sonic interaction is accepted by drivers in general and how it works in real traffic.

Conclusion and Relevance to session submitted

In sum, the current study indicates that sound may offer a cost-efficient solution for reducing visual distraction from visual displays and thus that it can tackle the challenge of making in-vehicle human-machine interaction safer.

PAPER NO. 15-0404-O

Comparison between Occlusion Methods for Measuring Distraction Caused by Smartphone Interaction

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ABSTRACT

Research Question/Objective

The occlusion method is an established method for measuring the visual demand from in-vehicle interfaces. The method is usually employed by means of occlusion glasses which can be automatically made opaque or transparent. However, occlusion can also be achieved by turning on and off the screen of the interface being studied. It can be hypothesized though, that glasses-occlusion requires more visual re-orientation efforts after each occluded interval which may give longer Total Shutter Open Times (TSOTs) than the method where only the interface screen is occluded.

Methods and Data Sources

Two experiments were conducted, with 10 participants (5 female) in Experiment 1 and 14 participants (7 female) in Experiment 2. In both experiments, participants were seated in a truck mockup and performed tasks on a smartphone. Two occlusion conditions were employed: 1) Occlusion with glasses, and 2) Embedded occlusion (turning the screen of the smartphone on/off). Participants also performed a baseline condition with no occlusion. In Experiment 1, five different tasks were performed in each condition: destination selection, dialing a phone number, dialing a contact, changing radio frequency and setting the alarm clock. For each task, a note showing the data to be entered was posted next to the smartphone, e.g. the number to be dialed.

The four tasks used in Experiment 2 were: visual-manual text entry, make changes in a truck driving log, dial a phone number and select item from a map (using pinch/swipe operations). The participants did not have support from any note but had to remember the data to enter for each task.

For both experiments, TSOTs and Resumability (R) were submitted to separate ANOVAs to reveal differences between occlusion and tasks.

Results

The results of Experiment 1 showed a main effect of occlusion type on TSOT ($p < .05$), where Glasses resulted in longer TSOTs ($M = 8.1$s) than Embedded ($M = 7.4$s). However, the interaction between occlusion and task was also significant ($p < .01$), and suggested that mainly the phone dialing task caused the difference in TSOTs. An explanation to this could be that tasks requiring more visual-spatial reorientation are more difficult to perform with glasses occlusion. A simpler explanation could be that participants needed to look at the note while dialing – which can be done during the occluded intervals with the Embedded method. The results from experiment 2 did not show any statistically significant effect of occlusion on TSOTs which suggests that the effects found in Experiment 1 were caused by the fact that participants had to look at the paper note while dialing.

Discussion and Limitations
The current experiments indicate that the embedded method gives TSOTs comparable to the glasses-occlusion method. However, one must be aware of the fact that there are practical differences between the methods which can lead to diverging TSOTs. The current experiments show that such divergence can occur when instructions are given visually.

Conclusions and Relevance to Session Submitted
The embedded occlusion method for evaluating distraction is nonetheless promising since it is easy to use and can be integrated in app developers' toolkit.

PAPERNO.15-0398-O

Reliability Improvement Needed in the Eye Glance Measurement Using Driving Simulator Test

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ABSTRACT
To improve the interface design of in-vehicle infotainment systems, robust evaluation methods are required. The Eye Glance measurement using Driving Simulator test (EGDS) defined in the Visual-manual NHTSA Driver Distraction Guidelines for in-Vehicle Electronic Devices is a promising candidate. However, the present study indicates that EGDS needs further refinement to become sufficiently robust. When two randomly selected groups of 24 drivers tested the same ten in-vehicle tasks following the EGDS protocol, test outcomes were not the same for the two groups. The analysis showed this to be a consequence of how the EGDS pass/fail criteria are calculated. As currently formulated, they make test outcomes highly dependent on between-driver variability. To assess the problem magnitude with repeated EGDS testing, another eight virtual test groups were created by for each group randomly selecting 24 of the 48 participants' test scores. The analysis showed that EGDS outcomes were 60 % consistent between these ten groups. While six tasks consistently passed or failed, the outcome for the other four depended on which group had tested them. This EGDS reliability problem could possibly be overcome by matching the criteria calculation principles to the underlying population variability.

PAPERNO.15-0423-O

Driver Behavior during Lane Change from the 100-Car Naturalistic Driving Study

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ABSTRACT
Lane changes with the intention to overtake the vehicle in front are especially challenging scenarios for forward collision warning (FCW) designs. These overtaking maneuvers can occur at high relative vehicle speeds and often involve no brake and/or turn signal application. Therefore, overtaking presents the potential of erroneously triggering the FCW. A better understanding of lane change events can improve designs of human-machine interface and increase driver acceptance of FCW. The objective of this study was to characterize driver behavior during lane change events using naturalistic driving data.
The analysis was based on data from the 100-Car naturalistic driving study, collected by the Virginia Tech Transportation Institute. The 100-Car study contains approximately 1.2 million vehicle miles of driving and 43,000 hours of data collected from 108 primary drivers. In order to identify overtaking maneuvers from a large sample of driving data, our study developed and validated an algorithm to automatically identify overtaking events. The lead vehicle and minimum time to collision (TTC) at the start of lane change events was identified using radar processing techniques developed in a previous study. The lane change identification algorithm was validated against video analysis which manually identified 1,425 lane change events from approximately 126 full trips.
Forty-five (45) drivers with valid time series data was selected from the 100-Car study. From the sample of drivers, our algorithm identified 326,238 lane change events. Lane change events were evenly distributed between left side and

right side lane change. The characterization of lane change frequency and minimum TTC was divided into 10 mph speed bins for vehicle travel speeds between 10 mph to 90 mph. A total of 90,639 lane change events were found to involve a closing lead vehicle. For all lane change events with a closing lead vehicle, the results showed that drivers change lanes most frequently in the 50-60 mph speed range. Minimum TTC was found to increase with travel speed, and the variability in minimum TTC between drivers also increased with travel speed.

PAPERNO.15-0452-O

Driver Vehicle Interface Design Assistance

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ABSTRACT
This paper provides an overview of the program of research involved in the development of a set of driver-vehicle interface (DVI) design assistance intended for vehicle-to-vehicle (V2V) technology applications. The research reviewed and performed under the NHTSA sponsored program of research (Human Factors for Connected Vehicles (HFCV), Safety Pilot DVI Evaluations, Driver Issues, and Integration Strategy) will culminate in a DVI Design Assistance Document for V2V technology applications. The results of the research will inform this document, which will be a set of Design Assistance topics and will describe appropriate human-centric design attributes for the DVI.

PAPERNO.15-0455-O

Auditory Alerts in Vehicles: Effects of Alert Characteristics and Ambient Noise Conditions on Perceived Meaning and Detectability

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ABSTRACT
Two complementary studies were conducted. In Study 1 (categorical perception of alerts), a series of experiments examined the key parameters that result in listeners perceiving a given sound as an urgent warning versus other less urgent message categories. Initial perceptual sorting experiments identified the most significant parameters and subsequent driving simulator experiments confirmed and refined the findings. Study 1 found that four auditory characteristics accounted for most of the variance in classification of auditory alerts as urgent warnings. Sounds were classified as alarms over 90 percent of the time when they had a peak-to-total-time-ratio (ratio of the time that the sound is at full intensity to the entire pulse duration including onset and offset) of greater than or equal to .7, an interburst interval of less than or equal to 125 ms, at least 3 harmonics, and a base frequency of greater than or equal to 1000 Hz. These results were observed initially in laboratory studies, and replicated during simulated driving. In Study 2 (warning perception in ambient noise environments), an experiment was conducted to investigate the effects of different in-vehicle ambient noise conditions on auditory signal detection and perception. Participants driving on a freeway experienced three ambient noise conditions (windows closed and no music, music playing, front windows open). Fifteen auditory alerts, presented at 65 or 75 decibels (A-weighted), occasionally occurred. Participants pressed a button as soon as they detected the sound, then provided ratings of the noticeability, urgency, and intended meaning of the sound. Study 2 found significant main effects for ambient noise condition and for alert sound for perceived noticeability, urgency, and response time to alert. Detection was impaired by the presence of music, and even more so with the front windows open. Even when auditory signals were heard, noise conditions modified their perceived urgency and meaning. There were also interactions between ambient noise condition and sound, indicating differences in how well sounds of similar loudness tolerated interference from noise. Results also demonstrate that the perceived urgency

and meaning of auditory messages can change under noisier ambient conditions, and some features of more noise-resistant signals were suggested by the data. The findings of this research may help interface designers to create auditory signals that indicate the appropriate type and urgency of message.

PAPER NO. 15-0156-O

Evaluation of Security Related Impacts on the Safety of Automotive Systems with Regard to Supporting Reaction Strategies for the Driver

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ABSTRACT

Objectives

The integration of modern IT technologies into vehicles brings up several new challenges in automotive systems engineering. While current technology aspires an exclusive use of electrical and electronic control systems for relevant functions, such as engine control or X-by-wire systems, growing dependency on electronic systems increases the vulnerability of modern cars to both accidental and intentionally forged IT incidents. Especially the constantly increasing complexity of and interdependencies between different automotive IT systems makes it difficult for the developers to foresee all potential fault conditions or to prevent unauthorized actions from taking effect. As if these problems were not enough of a challenge, especially in automotive IT environments IT- incidents can possibly also affect the safety of the car, its passengers and other road users.

Building on a study on IT security warnings (Tuchscheerer et al 2010) and comparing with corresponding ASIL levels, we carried out a driving simulator study to evaluate driver reactions to various error and security relevant scenarios.

Methods

Assuming that malfunctions of electronically supported control systems will endanger the safety of the car, a driving simulator study was designed and executed. These tests cover both security-related and safety-related sources of failures (i.e.: accidental or provoked malfunctions) and scenarios with different criticality (based on ASIL A, B, C, D – (ISO 2010)). The reactions of 40 uninformed drivers were observed and analyzed. In particular failures of engine, steering and brakes were executed in different road and traffic scenarios (e.g.: slow vs. high speed, low vs. high traffic density). The reactions of the drivers were recorded and, additionally, the controllability of the situation was observed as perceived by the drivers (using a think-aloud test). Furthermore, the study evaluated the potential of appropriate warning and reaction strategies that could support the reaction of the driver in critical situations as developed in (Tuchscheerer et al 2010).

Results

The results show differences in driver behavior within a specific failure situation and an even greater degree between various failure situations. We found different types of accidents following the loss of steering and braking function – but no accidents caused by the loss of engine function. Interestingly, the results show the highest rate of recognition for the engine turn off scenario, where as in the autonomous acceleration and loss of brake function 15-17% of drivers did not recognize the malfunction. Besides this, we introduce different strategies to warn and support drivers in such situations. Especially when losing the ability to steer and brake, the warnings showed positive impact if the driver is warned ahead and stops the car before the complete loss of those functions. When the warning appears together with the function loss, a significant improvement of crash count and severity could not be observed.

Conclusions

This work shows the impact security-related incidents can have on the safety of concurrent and future vehicles. It shows the potential of decreasing the severity of these incidents by using tailored warnings and shows a first evaluation of the feasibility of such an approach. It was shown that a loss of engine function leads to a safe stop of the car while a loss of steering or braking ability or an autonomous acceleration lead to an accident in 45% up to 71% of all cases. The severity of those accidents is not significantly correlated to the type of malfunction.

PEER REVIEW: PAPERNO.15-0171-O

Combining Coordination of Motion Actuators on a Truck Combination with Driver Characteristics

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ABSTRACT

Research Question/Objective

Human drivers can adapt and assess new situations. Computer controlled vehicles can do boring things millions of times in a reliable and quick way. A combination of these is therefore of course appealing. This paper deals with how to implement shared control between driver and driver assistance systems, ADAS, for motion control of a multi-unit truck combination. A truck combination has in general more actuators than controlled motions. This implies that actuator coordination is needed. Previous research has suggested Control Allocation, CA, methods as a way forwards. No one has however established a good connection between the driver and the CA layer. The objective here is to develop a method for this; where motion actuators are coordinated to maximize the manoeuvrability and stability of the truck combination and where driver feedback and capabilities become natural elements.

Methods and Data Sources

ADAS often support the driver in one direction longitudinal, lateral or roll. E.g. advanced emergency braking system, AEBS, is trying to control the longitudinal motion. Since motions are coupled also the other directions can be effected, e.g. AEBS activated on split friction may cause lateral deviation. It is therefore important to limit the assistance so that the induced disturbance is lower than what the driver can manage.

The developed method utilises the basis from the weighted least square formulation of a Control Allocation, CA, and problem with some modifications. The ability of the driver to handle disturbances is first estimated and expressed in terms of global virtual forces. These virtual forces create limits for the allowed induced error from unbalanced coordination of motion actuators. The limits are added into the CA formulation as linear constraints. This ensures that the ADAS system never jeopordazise the stability of the vehicle. It also gives continuous estimates of what control that can be realised while satisfying driver constraints. This information can be most valuable to the ADAS system.

The method is further extended by providing torque feedback to the driver indicating an upcoming disturbance even before it has occurred. This may potentially shorten the reaction time of the driver. And can thereby suppress the disturbance even more effective.

Results

The method was implemented and tested in Simulation. A high-fidelity two axle truck model with a trailer was used. Both the truck and the trailer had individually controlled brakes. The truck also had front axle angle overlay which was considered as an actuator. A verified driver-model was used in the simulation to control steering. The scenario AEBS activated on split friction was used an example to show the benefits. Results indicate that the developed method handled the constraints of the driver. The lateral deviation exposed was limited at the same time as braking distance was maximised.

Discussion and Limitations

The developed method showed good results in simulations and is also feasible in real-time applications for trucks. The later has been proven in other studies.

Conclusion and Relevance to session submitted

Safe Human-Machine Interface Design will become even more challenging as more automation is introduced. This is one contribution to that.

BIOMECHANICS #2: ADVANCES IN CRASH TEST DUMMIES, INSTRUMENTATION AND DATA ANALYSIS

Wednesday, June 10, 2015 | 8:30 a.m.- 12:30 p.m.
Chairperson: Philippe Vezin, France| Co-Chair: Yasuhiro Matsui, Japan|
TRACK A | Room: F3

PAPER NO.15-0048-O

Injury Simulation of Rear Seat Child Occupant in Offset Deformable Barrier Frontal Impact

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ABSTRACT
From 2016, Euro NCAP plans to assess child occupant protection performance with Q6 and Q10 dummies in a 64 km/h offset deformable barrier (ODB) frontal impact test. This paper describes research simulating this frontal impact test using a ten-year old (10YO) version of the Total Human Model for Safety (THUMS) and an FE model of the Q10 dummy. The changes in impact kinematics and injury values of the 10YO THUMS model were compared with the Q10 dummy under various load limiters (L/L) values ranging from 2 to 5 kN, and the differences between the two were examined.
Differences in the kinematics between the two mostly appeared during the second half of the test. As a result, the displacement of the head and chest of the Q10 dummy was smaller than that of the 10YO THUMS model. This result was probably because the thoracic plate of the Q10 dummy hindered the flexion of the thoracic spine. In addition, the chest upper deflection of the Q10 dummy resulted in higher injury values. This result was assumed to be because the shoulder belt was positioned close to the chest upper deflection gauge. In addition, the change in the chest upper deflection of the Q10 dummy was greater than that of the 10YO THUMS model, with a sensitivity of approximately four times as large. This result was due to the high force transmission ratio from the clavicle to the sternum.

PAPER NO.15-0432-O

Injuries and Kinematics: Response of the Cervical Spine in Inverted Impacts

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ABSTRACT
Given the frequency and severity of cervical spine injuries resulting from rollover crashes, it is critical to analyze the mechanism of cervical spine injury in this loading condition. In rollover crashes, roof-to-ground impacts can generate axial compression of the cervical spine, which can result in paralysis and death. This study was performed to compare injury type and severity between component and full body inverted vertex impact tests with post-mortem human surrogates (PMHS); a secondary aim was to determine how changes in vertebral kinematics resulted in changes in hear reaction loads. Five PMHS were suspended in an inverted seated position and then dropped from two heights to achieve 2 m/s (one subject once and another twice) and 4.4 m/s (all subjects) at impact. The subjects were dropped on a padded five-axis load cell to record the reaction force from impact. Each PMHS was instrumented with three blocks (each containing three accelerometers and three angular rate sensors) rigidly mounted along the upper thoracic spine and on the head. Injuries were determined using both CT scans and dissection following testing. Vertical force traces from the load cell reflect a similar two peak shape seen in previous full-body and component tests. High-speed (1000 Hz) X-ray video analysis shows the neck retains in its initial orientation but becomes increasingly compressed during the loading portion of the first peak. At the first peak, the cervical spine begins to curve, putting the cervical spine into

extension, with the center of curvature around C3 or C4, and continues into bending during the unloading of the first peak. The head then translates forward and the neck moves into flexion during the second peak. Each PMHS achieved a flexion injury in the upper thoracic spine or the lower cervical spine during the testing, which occurred during the second peak of the force trace, contradicting previous theories that injury occurs at the first peak, where maximum force occurs. These tests suggest that the direction of torso loading, impact velocity, and boundary conditions at the ends of the cervical spine all affect the kinematics during impact as well as the resulting injuries, and should all be taken into account when determining appropriate injury criteria and developing biofidelic ATDs to predict injuries in crash tests.

PEER REVIEW: PAPERNO.15-0170-O

Lower Leg Injury Risk Curves Based on Survival Analysis - Meta Analysis of Normalized Post Mortem Human Subject Experiments for Applications to Dummy Tests in Crashworthiness

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ABSTRACT

Research Question/Objective

To develop injury criteria for dummies, it is important to determine risk curves based on post mortem human subject experiments. Injuries to lower extremities continue to occur in frontal crashes. Axial loading through dorsal surface results in calcaneus and distal tibia fractures. Floor pan intrusion is a source for fractures to the foot-ankle and tibia-fibula complexes. Different groups have conducted studies to determine forces required to produce such injuries. Individual groups have described tolerances in the form of mean peak force. Some probability curves are based on differing assumptions. The purpose of this study was to conduct a meta-analysis of all published data and follow processes of International Standards Organization, developed/reported in 2012 (ISO/TC22/SC12/WG6). Specifically, axial load in association with age and normalization were used to develop risk curves.

Methods and Data Sources

Data were acquired from previous impact tests. This included intact foot-ankle and distal tibia-fibula complexes. Several sources were used for axial loading impacts: Roberts-1990, Begeman-1996, Yoganandan-1996, Kitagawa-1998, Funk-2002 and others. Calcaneus, distal tibia and pylon fractures were included. Analyses were performed using: modification of Median Rank Method (Mertz-Weber technique), Certainty Method, Logistic Regression, Consistent Threshold and Extended Consistent Threshold Approach, and Survival Analysis (Weibull, log-normal, log-logistic). Impact force was considered as main explanatory variable. Age was as a co-variable. Where available, acoustic sensor information was incorporated for fracture. Sub-injury data were left censored. Injury tests were right censored. For repeated tests on the same specimen, data were interval censored. Overly influential tests were identified. Distribution assumption/type was checked using quintile plots, best-fit distribution was chosen based on Akaike information criterion (AIC). Mean and 95% confidence intervals were computed. Quality indices were described at each probability level. Data were normalized to mid-size male and female using equal-stress equal-velocity approach. All risk curves are presented for 25, 45 and 65 year-old groups.

Results

A total of 111 tests alone were examined for impact force. Data analysis was based on age, force and type of probability distribution to determine the most efficacious survival analysis-based risk curves. Peak axial force was best represented by the Weibull survival distribution with three-type of censoring scheme. This distribution had the best AIC estimate. As a sample, forces at 5, 10 and 50% risk for the mid-size male for the 25 year-old: 7.9, 9.4 and 10.1 kN. Actual injury risk curves will be presented for all ages.

Discussion and Limitations

The present meta-analysis from the largest dataset from various groups of researchers focused on axial loading tolerance is applicable to modern frontal impacts as injuries with this mechanism continue to occur. Exclusion of other modes is a limitation.

Conclusion and Relevance to session submitted
These data provide normalized age/sex-based injury risk curves from >100 tests and use ISO recommended processes for developing survival analysis-based curves. They serve as improvements/robust injury criteria in future crashworthiness applications in frontal impact assessments and THOR use.

PAPERNO.15-0272-O

Comparison of HIC and BRIC Head Injury Risk in IIHS Frontal Crash Tests to Real-World Head Injuries

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ABSTRACT
The Insurance Institute for Highway Safety (IIHS) has been measuring head injury criterion (HIC), a measure based on linear impact skull fracture data, to assess head injury risk in its front crash tests since 1995. In 2012, IIHS added instrumentation to measure brain injury criterion (BrIC), a rotationally based injury measure derived from animal data correlated to humans through computational modeling. BrIC is intended to complement HIC rather than replace it. Head injury risk associated with HIC and BrIC values measured with a Hybrid III dummy in 138 front crash tests was compared with real-world injury rates in similar frontal crash configurations calculated from the National Automotive Sampling System Crashworthiness Data System (NASS CDS) database.
NASS CDS identified 1.3-5 percent AIS3+ head injury rates in crashes similar to the test configurations. The mechanisms of injury represented by HIC and BrIC are a subset of all head injuries; therefore, the NASS-indicated head injury rates inherently may be an over-prediction of injuries directly applicable to these formulas. In crash tests, HIC AIS3+ head injury risk ranged 0-22 percent and BrIC AIS3+ head injury risk ranged 3-85 percent. BrIC AIS3+ head injury risk greater than 50 percent was associated with a variety of head kinematic events including front airbag loading, head contact with instrument panel, and non-contact forward excursion.
The published injury risk curve for BrIC indicates that crash tests represent significantly higher serious head injury risk than observed in real-world crashes of similar configurations. Hybrid III may produce exaggerated measures of BrIC or, if accurate, the BrIC formula may need to be reexamined against the underlying animal test data to determine the limitations of BrIC, and the proposed injury risk curves need to be re-evaluated against real human injury risk. Despite its origins as an indicator of skull fracture risk, the range of HIC-based head injury risk observed in crash tests more closely reflects the real-world head injury rates than the range of BrIC-based head injury risk.

PAPERNO.15-0288-O

Instrumentation Technique for Measuring Six Degrees of Freedom Head Kinematics in Impact Conditions Using Six-Accelerometers and Three-Angular Rate Sensors (6afç Configuration) on a Lightweight Tetrahedron Fixture

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ABSTRACT
The ability to measure six degree of freedom head kinematics in impact conditions (i.e. motor vehicle crashes and sport activities) plays an important role in injury assessment of the head/neck complex. Potential accuracy of head instrumentation schemes have recently been improved by using advanced angular rate sensors, so in this study an instrumentation technique for obtaining accurate head kinematics in impact conditions using an external fixture is

proposed and validated. The methodology proposed in this study utilizes six accelerometers and three angular rate sensors (6afç) on a lightweight tetrahedron fixture (t6afçfwfnoriginally designed for measuring head kinematics of post mortem human surrogates (PMHS) in car crash scenarios using a nine accelerometer array package (NAAP) configuration (tNAAP). A Hybrid III 50th percentile male anthropomorphic test device (ATD) head containing an internal nine accelerometer array package (iNAAP) was used to validate the t6afç method proposed in this study. The t6afç instrumentation was installed on a tetrahedron fixture which was attached externally to the Hybrid III ATD head, tested in direct contact tests of various severities, and then compared to data measured from the iNAAP of the Hybrid III ATD head which provided the kinematics gold standard to validate the proposed technique. Results indicate that angular acceleration obtained from the t6afçfnscheme was comparable to that determined from the iNAAP scheme in the head impact conditions, showing normalized root mean squared deviation (NRMSD) values less than 5%. Transformed linear acceleration from the t6afçfnto the center of gravity (CG) of the Hybrid III ATD head was also comparable to acceleration measured directly from the accelerometers at the CG, exhibiting less than 5% NRMSD. Accurate angular acceleration and velocity are important to obtain accurate transformed acceleration. Since the t6afçfnangular acceleration component of the transformed linear acceleration at an inaccessible point was shown to have equivalent accuracy to iNAAP (less than 5% error), and the angular velocity component of t6afçfninstrumentation should be more accurate than the tNAAP scheme (since it is directly measured by the ARS as opposed to using numerical integration as in tNAAP), the t6afçfnscheme should yield more accurate transformed linear acceleration at an inaccessible location than the tNAAP scheme. The proposed instrumentation should aid in the development and evaluation of head, neck and brain injuries in future testing.

PAPERNO.15-0207-O

A Study of Brain Injury Mechanisms in Vehicle Crashes

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ABSTRACT

Brain injury has been researched since the 1940s and various methodologies have been discussed for evaluating brain injury risk in vehicle crash tests. In recent years, an angular velocity based brain injury criterion (BrIC) has been proposed by the National Highway Traffic Safety Administration (NHTSA) for use in regulatory or consumer vehicle safety assessment tests. One of the brain injury mechanisms can be explained by relative displacement between the brain and skull, resulting in brain deformation and strain. This paper states a hypothesis of this brain injury mechanism using a simple mass-spring-damper model. Then the hypothesis was verified by the Simulated Injury Monitor (SIMon) version 4.0, a finite element model of the human head developed by NHTSA, using a cumulative strain damage measure (CSDM) as the brain injury metric. In consequence, CSDM varies according to the input loadings, which have the same peak angular velocity but different levels of peak angular acceleration and loading durations. These results suggest that in order to evaluate brain injury risk accurately, an angular velocity based criterion may not always be sufficient and it may be necessary to consider the peak value of angular acceleration and the corresponding loading duration. This hypothesis was applied to NHSTA research test data to prove its validity. It was found that brain injury risk predicted by CSDM can be comparatively lower than that predicted by BrIC and vice versa.

PAPERNO.15-0397-O

Occupant Behavior and Brain Injury in NHTSA Oblique Test

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ABSTRACT

The National Highway Traffic Safety Administration (NHTSA) found that a large number of fatalities occurred in crashes involving poor structural interaction between the striking and the struck vehicles, such as corner impacts, oblique crashes, or impacts with narrow objects.

NHTSA proposed the oblique test that can reproduce vehicle crush, occupant kinematics, and risk of injury in vehicle-to-vehicle crashes, an offset impact between a research moving deformable barrier (RMDB) and a stationary vehicle at a 15 degree angle.
Recent research for NHTSA oblique test with THOR ATD showed the lateral movement of both occupants, so that the driver¡¯s head contact with door or between door and steering wheel. For the far-side occupant, the head contact with center IP and the brain injury risk predicted using BrIC is higher than SOI.
The objective of this paper is to investigate and understand the effect of airbag performance on the occupant kinematics and related injury during NHTSA oblique tests. This paper focuses on effect of various airbag parameters corresponding to the dynamic stiffness.
The research integrated the injury analysis with a crash testing and computer simulation. MADYMO was used to create a NHTSA oblique test environment. Both 50th percentile THOR ATD and Hybrid III in MADYMO were respectively used to simulate occupant kinematics and injuries for the driver and passenger occupant. Airbag models for curtain airbag and passenger airbag are used in the simulations in order to understand the effect of various restraint system concepts on occupant kinematics and injuries.
In this paper, driver side airbag and passenger side airbag are investigated for both near-side occupant and far-side occupant. CAE models are used to show their advantages and limitations. Further enhancements are proposed to improve the correlation of these occupant models. Passenger side airbag and driver side airbag are investigated to reduce the brain injury and head contact with compartment. NHTSA oblique test case is used to demonstrate the effectiveness of the airbag variations.
Limitations of the current airbag model used for NHTSA oblique test were highlighted. Vent hole was modified to improve the head injury.
For reducing the brain injury risk of occupant in an NHTSA oblique test, it was found counter measures which didn't cause head rotation was effective.

PAPERNO.15-0216-O

Proposal for a Modified THOR Lower Abdomen Including Abdominal Pressure Twin Sensors

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ABSTRACT

This paper presents the evaluation of a modified THOR-NT lower abdomen which includes two abdominal pressure twin sensors (APTS®) as replacement for the displacement measurements. Further small changes such as the addition of small masses in front of the abdomen have also been made to better mimic the response of the PMHSs under seat belt loading. As a result, the biofidelity of the prototype abdomen was improved compared to THOR-NT standard abdomen. The addition of the small masses succeeded in increasing the initial peak force of the force-penetration response under seat belt tests. In rigid bar impacts, the prototype force-deflection response stayed longer in the corridor. The pressure measurement was repeatable and discriminated the various impact speeds as well as the impact direction. The pressure peaks were proportional to force and penetration peaks. This study demonstrates the feasibility of introducing the APTSs into THOR lower abdomen and makes proposals for further biofidelity enhancements.

PAPERNO.15-0116-O

Development of a High Energy Side Impact Dummy

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ABSTRACT

A high energy side impact dummy (HE-SID) was developed for special vehicle development used for law enforcement and VIP protections subjected to improvised explosive device (IED). MIL-SID, i.e. ES-2 ATD with Hybrid III head/neck and MIL-LX design, was used to develop the test rig and define inputs to mimic the IED test conditions. It was found that the MIL-SID shoulder and rib modules were not durable enough to survive the impact during the testing. In addition, the shoulder biofidelity was lacking and requires improvement. A new shoulder structure was designed to improve the shoulder biofidelity. Finite element analysis was conducted to optimize the shoulder design according to the target biofidelity as defined by a series of 12 PMHS shoulder impacts. The MIL-SID shoulder cam design was replaced with a single shoulder rib integrated with damping materials. A 3D deflection measurement system was developed to measure the shoulder deflections. The 3D deflection measurement system consists of a linear potentiometer and two rotary potentiometers. An algorithm was developed to calculate the deflections at its shoulder joint attachment location. Hardware was fabricated and retrofitted in a MIL-SID for verification and validation. The preliminary test shows that the thorax durability issue was addressed. The ATD was able to withstand numerous tests without any damage. The new shoulder design demonstrated good biofidelity under high energy test conditions.

PAPERNO.15-0339-O

Impact Responses of THOR Mod Kit under Different Conditions in Sled Tests and Vehicle Crash Tests

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ABSTRACT

In order to contribute to the development and improvement of the THOR dummies, the impact responses of the THOR Mod Kit were compared with the THOR-NT and the Hybrid III, based on the kinematic and dynamic responses to different conditions in the frontal sled and vehicle crash tests. In a 56 km/h frontal sled test where a dummy was installed on the driver seat of a white body, the responses of the THOR Mod Kit with SD3 shoulder to the differences of the seating procedures and restraint conditions were evaluated comparing with the THOR-NT and the Hybrid III. Moreover, two crash tests using a small passenger car at 55 km/h FWRB and 64 km/h ODB corresponding to JNCAP conditions were conducted, and the responses of the THOR Mod Kit were compared with that of the Hybrid III.

Difference of seating procedure affected the responses of the thoracic deflection, abdominal deflection, and iliac force, etc. Compared with the THOR-NT, the THOR Mod Kit clearly showed difference on each measurement location and the forward displacement of its shoulder on the unrestrained side was more pronounced. Regardless of the D-ring positions, the shoulder belt slippage didn't occur in the Hybrid III, whereas belt slippage occurred in the THOR Mod Kit when the D-ring was at the lowest position. When the load limiter force of the seatbelt was higher, forward displacements of the thorax became smaller in both the THOR Mod Kit and the Hybrid III and the neck flexion of the THOR Mod Kit became larger. Accompanying the difference of kinematics, the responses of the head acceleration, neck force and thoracic deflection also differed. In both the FWRB and ODB tests, the maximum rotation angle of the ankle eversion exceeded the preliminary IARV for the THOR at the rebound phase, not at the intrusion phase.

From the results above, it turned out, that the THOR Mod Kit response to the difference in seating procedure was more sensitive than that of the THOR-NT. The sensitivity of the THOR Mod Kit to the D-ring position was higher than that of the Hybrid III, and that the difference of load limiter affected the difference of kinematics and dynamic responses of the upper body in both the THOR Mod Kit and the Hybrid III.

Restraint System Design and Performance Challenges: Addressing the Needs of Diverse Populations (Age, Gender, Stature)

Wednesday, June 10, 2015 | 8:30 a.m.- 12:30 p.m.
Chairperson: Lotta Jakobsson, Sweden
Co-Chair: Lex van Rooij, The Netherlands|
TRACK B | Room: F4

PEER REVIEW: PAPERNO.15-0122-O

A Simulation Study on the Efficacy of Advanced Belt Restraints to Mitigate the Effects of Obesity for Rear-Seat Occupant Protection in Frontal Crashes

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ABSTRACT

Research Question/Objective

Recent field data analyses have shown that the safety advantages of rear seats relative to the front seats have decreased in newer vehicles. Separately, the risks of certain injuries have been found to be higher for obese occupants, who experience poorer belt fit than normal-weight occupants. Belt restraints with load limiters and pretensioners, which are now common in front seats, might improve protection for rear-seat occupants and reduce the increased risks associated with obesity. Therefore, the objective of this study is to investigate the effects of advanced belt features on the protection of rear-seat occupants with a range of body mass index (BMI) in frontal crashes.

Methods and Data Sources

A finite element model of a rear-seat environment for a compact vehicle was developed and validated against dummy responses in a sled test under a crash pulse of 56 km/h. In previous work, a midsize-male whole-body human model based on THUMS 4 was modified to represent occupants with BMI from 25 to 40 kg/m2 and validated against cadaver tests. In the current study, 28 frontal crash simulations were conducted, including 4 simulations with a standard 3-point belt in rear seats and 24 simulations with different seatbelt configurations sampled by the Uniform Latin Hypercube method. The design parameters included BMI (25/30/35/40), load limits (3kN/4kN/5kN), anchor pretensioner (yes/no) and lap belt routing relative to the pelvis (low/high). The injury measurements analyzed in this study included head and hip excursions, chest compression ratio, and torso angle (defined by the hip-shoulder-line passing the vertical direction). ANOVA and ANCOVA were used to test the significance of the results, which are presented when significant with $p<0.05$.

Results

Higher BMI was associated with greater head and hip excursions and larger chest compression ratio. Higher belt routing increased the hip excursion and torso angle, which indicates a higher submarining risk. Decreasing the load limiters force

increased head excursion but decreased chest compression ratio. The anchor pretensioner reduced hip excursion and torso angle. Chest compression ratio was significantly correlated with maximum torso angle. Occupants with higher BMI have to use higher belt load limits to reach similar head excursions as those in lower BMI occupants.

Discussion and Limitations

These simulations suggest that optimizing load limiter and adding pretensioner(s) can reduce some risks associated with obesity, but conflicting effects are observed. For example, a load limiter can be used to reduce chest compression at the cost of increased head excursion. Different optimum load limits for occupants with different BMI levels indicated an advantage for adaptive restraints. This study is limited by the single crash condition, single seat geometry, limited belt fit conditions, and the use of human models with a single midsize-male stature. However, this study demonstrated the feasibility and importance of using a human model to present occupants with various BMI levels and their associated body shapes and belt fits, which cannot be achieved by the dummy models.

Conclusion and Relevance to session submitted

A seatbelt system capable of adapting to occupant size and body shape could improve protection for obese occupants in rear seats.

PAPERNO.15-0023-O

Analysis of Abdominal Injuries Caused by the Submarining Phenomenon in the Rear Seat Occupants

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ABSTRACT

Improvements to vehicle safety have targeted mainly the front seating positions, where the rate of seat belt usage was high and there were many casualties. Recently, rear seat occupant protection become an important challenge, with an increase in usage of seat belts by rear occupants due to new regulations and new performance criteria defined by Japanese and European vehicle assessment programs for rear seating occupants. Some prior analyses of accident data indicate that rear seat belted occupants tend to be injured in abdominal regions by the seat belt in comparison with front seat occupants. Due to this, the need to study the cause of abdominal injuries and how to countermeasure it, is becoming indispensable for improving the safety of the rear seat occupants. The following two phenomenons are considered as factors which great impacts on abdominal injuries due to the seat belt: the submarining phenomenon, lap belt sliding on iliac and intruding into abdominal region, and the incorrect routing of the belt, lap belt existing initially on abdominal region. However, the relationship between these probable causes and the abdominal injuries in the real world accident is not expressly described in prior studies. Therefore, first, the frequency of the abdominal injuries caused by the submarining phenomenon was estimated by micro analysis of the accident data. Second, the influence on abdominal internal organs, to which the lap belt load was applied, was analyzed using human body FE model THUMS. The results of this analysis indicated that serious effect might be applied to abdominal internal organs. As the routing of the lap belt on the pelvis was shown as being very important in this study, a parametric study using Madymo was conducted to determine additional factors that might influence the proper routing of the belt on pelvis. This study narrowed down the factors with big contribution and explains how they were determined.

PAPERNO.15-0018-O

Advanced Seat Belt Reminder System for Rear Seat Passengers

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ABSTRACT
Advanced seat belt reminder systems with audiovisual warnings have proven to be highly effective in increasing the belt wearing rates of a vehicle's front seat occupants. While the availability of such advanced SBR systems for the front seats is almost common in some markets and fast-growing in others, also thanks to NCAP incentives, the systems available on the rear seats have so far only offered a basic functionality. In 2014, an upgraded SBR function entered the mass market, and the world's first car with an advanced rear seat SBR system including occupant detection was launched on the Japanese market. This vehicle, the Subaru LEVORG, offers an advanced audiovisual SBR warning for the rear outboard seating positions. This advanced function is enabled by occupant detection sensors designed to detect human rear seat occupants, while being robust against the detection of child restraint systems (CRS) or other objects frequently transported on a vehicle's rear seats. The robustness of the occupant detection and the object non-detection has been tested extensively. Occupants shifted their position forward and laterally away from the nominal seating position. A multitude of CRSs and objects were tested to ensure that they do not trigger unnecessary warnings. Advanced rear seat SBR systems have the potential to significantly increase the belt wearing rates, especially as those tend to be much lower on the rear than on the front seats in almost all countries. As belt load limiters and belt tensioners are more and more available for the rear seats, the advanced SBR systems ensure that more rear seat occupants will benefit from the restraint system enhancements.

PAPERNO.15-0263-O

Influence of Impact Type and Restraint System Triggering Time on Injury Severity in Frontal Impact Crashes

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ABSTRACT
The safety performance of cars is evaluated using standard tests. These standard tests are normally performed with full overlap or 40% overlap from the corner in different speed ranges. Analysis of accident data indicated that the injury severity of car occupants that were involved in accidents that are different compared to the standard tests (e.g., central pole impact) is considerably higher than for those that are similar to the standard tests. One of the discussed possible reasons for this observation is that the restraint system triggering might not be appropriate for these situations.

The combination of NASS CDS data with the NASS EDR data allows analysis of the accident circumstances, the restraint system triggering times and the injury situation in frontal impact accidents. The result of this analysis is a grouping of accident situations with corresponding injury severities and restraint system triggering times. These groups are rechecked using the GIDAS data to confirm the influence of the accident circumstances on the injury severity, as restraint system triggering time is not available in the GIDAS data sample.

The restraint system trigger time depends on several factors (e.g., delta-v, impact configuration (e.g., involving both long members, only one long member, or no long member), impact angle etc.). While most of the differences appear to be sensible for optimal protection (e.g., at higher delta-v the airbag is needed earlier) the differences for the different impact configuration appears to be critical with respect to injury severity levels of the frontal occupants.

The shown correlation between crash configuration, restraint system triggering time and injury severity does not necessarily mean that there is a causative relation between triggering delay and increased injury severity. However, it is likely that there is a causative relation.

PAPER NO. 15-0337-O

Crash Protection Offered to Small Occupants in an Offset Frontal Crash

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ABSTRACT

ANCAP crash tests are conducted to well-established protocols and use driver and front passenger anthropomorphic test devices (ATDs) that represent 50 percentile (%ile) adult males. Most modern vehicles do well in these crash tests. However, concerns have been raised about the protection provided to smaller occupants.

In 2013 ANCAP conducted a 64km/h frontal offset crash test of a Holden Commodore VF Ute (single-cab pick-up) with two Hybrid III 50%ile male ATDs (AM50). In 2014 the opportunity arose to conduct a further research crash test of a Commodore VF Ute using a small adult female driver ATD (5%ile adult female) and a 6 year old child ATD (Hybrid III 6) in a booster seat in the front passenger seating position.

The purpose of the research test was to determine whether the two occupants had an increased risk of injury, compared with the adult male ATDs.

The occupant injury measures for the smaller occupants were compared to the results of the previous vehicle crash test (with 50%ile adult male front occupants) in order to make comparisons between the level of protection offered to occupants of different sizes for this type of crash. Furthermore, the authors examined whether the restraint and airbag systems that perform well for 50%ile adult male occupants provide comparable protection for smaller occupants and whether there are any additional hazards for smaller occupants.

The outcome of the research was that for the case examined, with the available methods for assessing injury risk, smaller occupants appear to be offered comparative protection in a frontal offset impact for this particular vehicle model. It is apparent that the test vehicle manufacturer included consideration of smaller occupants in the design and development of this vehicle model.

PAPERNO.15-0371-O

Innovative Seat Belt System for Reduced Chest Deflection

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ABSTRACT

An innovative seat belt concept aimed at reducing chest injuries was evaluated by means of mechanical tests and mathematical modelling. The tools used were mechanical THOR dummy, mathematical THOR dummy model, THUMS human body model and (Post Mortem Human Surrogates) PMHS. The potential chest injury reducing benefits with an innovative seat belt concept relative to a state of the art belt system was evaluated in sled tests. The reference belt system was a state of the art belt system with a pretensioning of 2kN at the retractor, a force limiter of 4.5kN and an outer lapbelt pretensioner with a pretensioning force of 3.5kN. The innovative seat belt concept was consisting of a retractor equipped with a 2kN pretensioner at the retractor, a force limiter of 6kN and two 3.5kN pretensioners at the buckle and outer lap belt anchorage. The belt was split at the buckle and the lower end of the diagonal belt was moved 50mm forward. With the altered belt geometry the load on the lower part of the chest was reduced and the peak chest deflection was reduced relative to a state of the art belt system. In mechanical sled tests with rigid seat and an impact velocity of 35 and 30kph with the THOR dummy peak chest deflection was reduced by 8.0mm compared to a state of the art belt system. In the corresponding sled model with the THOR dummy model peak chest deflection was reduced by 13mm. Head x-displacement was increased by 26mm for the mechanical THOR dummy and 24mm for the THOR dummy model. For the THUMS model pleak chest deflection was reduced by 10mm with the split buckle system.

Generally for the mechanical THOR dummy, the THOR dummy model and the Autoliv THUMS model peak chest deflection was reduced by approximately 8-13mm with the split buckle belt system while only a minor increase in head x-displacement was observed relative to a state of the art belt system.

PAPERNO.15-0381-O

Innovative Restraints to Prevent Chest Injuries in Frontal Impacts

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ABSTRACT

By 2050, 21% of world population is expected to be older than 60 years. This age shift poses a serious challenge to the protection of car occupants, as fragility and frailty are associated to increasing age. Advanced restraint systems that aim to reduce chest loading by implementing load limiters or inflatable parts have been introduced in the market over the last years. This paper investigates the kinematics and dynamics of two surrogates (THOR dummy, Post Mortem Human Surrogates or PMHS) in 35 km/h impacts under the action of two different restraints: a pretensioning, force-limiting seat belt (PT+FL) and a concept design consisting of two separate shoulder and lap belt bands (split buckle system or SB). Three repeats per condition where done with the THOR dummy, while only one PMHS was tested per restraint system. With respect to the PT+FL, the results from the THOR tests showed that the SB seat belt decreased chest deflection significantly without a substantial increase of the forward displacement of the head. The PT+FL belt allowed the pelvis of the PMHS to move forward preventing the rotation of the torso and therefore reducing the forward excursion of the head. The PMHS test with the SB resulted in improved kinematics compared with the PT+FL. A complete understanding of the kinematics and dynamics induced by these restraints would require additional PMHS tests.

PAPERNO.15-0443-O

Investigation of Rear Seat Occupant Potential Injury Risk Based in Seat Belt Configurations

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ABSTRACT

The occupants of all ages and sizes can be seated in the rear seats. But legal requirements regarding the qualification of the second seat row restraint system with anthropomorphic test devices (ATDs) currently do not exist. The protection of frontal seat passengers in both driver and front seated occupant has been more focused from the auto industries as well as regulatory bodies more than 40 years. Fortunately, their interests have been extended to rear seat occupants especially children and female occupants in recent years. However, the current available safety devices for the rear seat occupants are standard seat belt system only. Also, the majority of the rear seat occupant studies were focused to evaluate and protect child either CRS or using seat belt restrained in rear seat. The rear seat seemed to offer the greatest protection to children 0¨C12 years. Children seated in the rear seat had a lower risk of death compared with front seat passengers whether or not they were restrained. However, among adolescent and adult passengers, the rear seat offered less protection with increasing age and when restraints were used.

As a pilot project in Korea, total 452 accident cases have been collected and numbers of injured occupants (in patient) were 698. Drivers were 383 (54.9%), front passengers were 164, 2nd row left side seat were 47 (6.7%), 2nd row right side seat were 82 (11.6%), 2nd row middle seat were 15 (2.1%), and the remains are 3rd and 4th row seat occupants. Results from ISS injury severity analysis, the occupant of driver seating position has the highest ISS scores, 7.8¡À10.3, while front passenger (7.7¡À12.9), 2nd middle seat (6.3¡À7.7), 2nd left seat (6.1¡À9.3), 2nd right seat 6¡À11.7), 3rd left seat (6¡À0.0), 3rd middle seat (5¡À0.0), and 3rd left seat (2.8¡À1.7). Although the analysis was based on the limited numbers of data set, the safety of the rear seat adult occupants can't be ignored. Especially, the majority of rear seat potential occupants may be vulnerable occupants such as child, female with children, pregnant woman, and elderly.

In this study, the rear seat belts anchorage locations of the current domestic passenger vehicles were investigated to evaluate the influence of rear seat belt anchorage geometrical configurations in terms of the rear seat passenger safety. The sled type simulation models are developed with three point belts are fitted on the Hybrid 5th percentile dummy and Hybrid 50th percentile dummy. The injury value, particularly HIC15 and Chest deflection were examined to evaluate the contribution of rear seat belt anchorage locations.

PAPERNO.15-0130-O

Preliminary Study of Roof Airbag Protecting Rear-Seat Occupants in Frontal Impact

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ABSTRACT

A kind of innovative Airbag, Roof Airbag (RAB), with external straps is studied via virtual engineering, which provide protection to rear-seat occupants in frontal impact. Frontal sled model with AF05 female dummy is generated in LS-DYNA, which is well correlated with full vehicle frontal crash tests in terms of the kinetics and injuries of the dummy. In addition, it is adapted for AF50 and AF95. Based on above models, different configurations of restraint system are studied, different levels of load limiter, belt with or w/o pretensioner, with or w/o RAB for instance. It can be summarized that roof airbag with low level of belt load limiter and pretensioner could provide protection to most size of rear-seat adult occupants as good as that of front-seat occupants in frontal impact.

PEER REVIEW: PAPERNO.15-0077-O

Census Study of Real-Life Near-Side Crashes with Modern Side Airbag Equipped Vehicles

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ABSTRACT

Research Question/Objective

Investigate the injury distribution and mechanisms for belted near-side seated injured occupants in airbag equipped modern vehicles.

Methods and Data Sources

Case-by case study of NASS/CDS data for side impacts (GAD L&R) with modern side airbag equipped vehicles (MY>1999) where a belted occupant was seated adjacent to the intruding structure (near-side). Rollovers were excluded and only front-seat occupants above 10 years included. The analysis was made on both raw and weighted data.

Results

For MAIS2+F injuries (N=240) thorax was the most frequent injured body region followed by the head and lower extremities. The median deformation was 220mm and the most frequent crash was a passenger car impacted by a utility vehicle (40%) followed by car-to-car (23%) and car to fixed object (22%). The most frequent injury was rib fractures (53%). Outboard (adjacent to intruding structure) rib fractures occurred on 38%, and inboard fractures on 19% of the occupants. Second most frequent injury was pelvis fracture (33%) followed lung injury (31%) and brain injury (24%). For the non-senior occupants (10-59 years) the collision partner was high (relative to the target vehicle) in 66% of the crashes compared to 50% for senior occupants (>60 years) where a larger portion were car-to-car crashes. For the non-senior occupants median deformation was 250mm and MAIS2+F injuries to the head (concussions and brain injuries) were most frequent (49%) followed by rib (37%) and pelvis (36%) fractures. For non-senior occupants with a neighbour present (N=82) a large increase in lung injuries and increase of brain injuries, inboard rib and clavicle fractures, and aorta ruptures was shown compared to the single non-senior drivers (N=102). For the senior group median deformation was 150 mm and rib fractures (64%) were most common followed by pelvis fractures (35%) and head injuries (34%). For the senior occupant with a neighbour (N=39) the frequency of inboard rib fractures, total number of rib fractures, and pelvis fracture increased compared to the injuries sustained by the single senior drivers (N=16).

Discussion and Limitations

The increased frequency of inboard rib fractures for the senior near-side occupant, and the increased frequency of lung injuries to the non-senior occupant, where a neighbour was present is likely a result of the occupant-to-occupant interaction. The majority of head injuries were not related to fractures but to non-contact brain injury or concussive injuries from impact to vehicle interior or a high collision partner. Presence of a side airbag protecting the head reduced the number of concussions compared to no airbag coverage of the head.

Conclusion and Relevance to session submitted

The detailed analysis of the crashes shows that occupant-to-occupant interactions influenced the injury outcome especially for senior occupants while a high deformation and a high collision partner caused a majority of the injuries to the non-senior occupants. The results can be used to improve side impact restraint systems and test procedures evaluating their performance. The analysis of injury frequency also provide input on injuries to assess using finite element human body models for development of improved side restraint systems.

PAPER NO. 15-0384-O

Gender Differences in Occupant Posture and Muscle Activity with Motorized Seat Belts

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ABSTRACT

The aim of this study was to assess gender differences in the posture and muscular activity of occupants in response to pretension from motorized seatbelts. Male and female vehicle occupants were tested in both front seat positions during normal driving and autonomous braking. This data is useful for the development of human body models (HBM), and increases the understanding of the effects of motorized belts.

Kinematics and electromyography (EMG) were analyzed for 18 volunteers (9 male, 9 female) subjected to autonomous braking (11 m/s2 deceleration) during real driving on rural roads. Two restraint configurations were tested: a standard belt and a motorized belt, activated 240 ms before the initiation of braking. Statistical comparison of volunteers' posture and normalized EMG amplitudes was performed to understand differences incurred by the motorized belts, as well as to compare response across gender and role (occupant position within the vehicle). Data was analyzed both prior to and at vehicle deceleration, which occurred 240 ms after motorized belt onset.

Motorized belts significantly affected all postural metrics, and significantly elevated the activity of all muscles compared to typical riding. Though increases in muscle activity were small at deceleration onset compared with typical riding for male occupants and female passengers, female drivers demonstrated significantly larger increases in muscular activity: between 5 and 13% of the maximum voluntary contraction (MVC). At deceleration onset, standard belts showed little change in posture or muscle activation, with the median changes being well within the ranges exhibited during typical riding for all groups (i.e. not distinguishable from typical riding). Typical riding postures of males and females were similar, as were muscular activation levels—generally less than 5% of the MVC. However, drivers exhibited significantly higher muscular activity in the arm and shoulder muscles than passengers.

Limitations include the repeated nature of the testing, as prior work has shown that habituation across trials alters occupant response compared to that of unaware occupants. However, randomization of the trial order helped mitigate potential habituation effects. Another limitation is the sample size of 18 volunteers.

An important finding of this study is that the increase in occupant muscular activation seen with motorized belts was gender-specific: at deceleration, the change in activation of most muscles was significantly different across gender and belt type, with female drivers exhibiting larger increases in muscular activation than male drivers or passengers of either gender, particularly in the arm muscles. These activations appeared to be startle responses, and may have implications for interactions with the steering wheel and motion during a braking or crash event. This warrants further studies and stresses the importance of quantifying male and female subjects separately in future studies of pre-crash systems.

Crash Avoidance #3: Connected and Automated Vehicles

Wednesday, June 10, 2015 | 8:30 a.m.- 12:30 p.m.
Chairperson: Tim Johnson, United States| Co-Chair: Jonas Sjöberg, Sweden|
TRACK C | Room: F1-F2

PAPERNO.15-0106-O

Automatic Control of Vehicle Steering System during Lane Change

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ABSTRACT

Mechatronic systems assist drivers in safe driving of cars more and more often. A vision of a totally automated car realizing many manoeuvres without driver's participation becomes closer and closer. The lane change manoeuvre is one of the basic manoeuvres on the ground of which sequences of complex manoeuvres can be composed, e.g. vehicle passing or obstacle avoidance manoeuvre. For those reasons, automation of lane change manoeuvre appears to be essential for automation of vehicle driving and is a subject of numerous research studies. Within a research project, the authors have undertaken extensive analytical studies on application of active steering system EPS in automatic driving of a two-axis truck equipped with typical elements of ESC system and obstacle detectors, as well as road monitoring systems.

The present paper focuses on theoretical aspects of the synthesis of an automatic controller for the EPS active steering system. Simulation studies of an automatically controlled lane change manoeuvre illustrate the application of the methodology. The basis for theoretical considerations and numerical studies is the mathematic model of the controlled system (vehicle) and the controller. A complex, detailed description of the dynamics of a two-axis truck, taking into account nonlinearities and vehicle motion in 3D space, is included in the simulation model. The model of the controller is based on a reference model which is significantly simplified and hence is highly effective for carrying out necessary computations in real time. An algorithm of the controller operating as a Kalman regulator in a closed loop system is developed on the basis of this model. The time decomposition of the automatic control process into two phases –lateral displacement of the vehicle and stabilization of its position – is an essential, original distinguishing feature of the algorithm. Thanks to this decomposition, the structure of the control system is relatively simple. Feedback signals provided by the sensors available in a typical ESC system (lateral acceleration, yaw velocity) are used in the control process. The vehicle reference model and resulting control algorithms are presented in the paper. Simulation results refer to a two-axis truck travelling with a constant velocity on a straight, uniform road. At certain time instant the vehicle starts executing the lane change manoeuvre. Simulations were carried out for a number of cases with varying model parameters. That allowed estimating the sensitivity of the control algorithm to both perturbations of vehicle's physical and operational parameters and to perturbations of parameters related to the obstacle. The results of simulations show that the proposed concept of the vehicle automatic control performs well in computational tests. The method of automatic execution of the lane change manoeuvre presented in the paper can offer an attractive alternative for vehicle control engineers and researchers working in the fields of active steering systems of vehicles, including commercial trucks.

PAPERNO.15-0109-O

Automated Driving Functions Giving Control Back to the Driver: A Simulator Study on Driver State Dependent Strategies

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ABSTRACT
Many car companies and other organisations are working hard to get automated driving on the road. Where some prefer driverless cars, most foresee a future where control of the vehicle will be shared between the driver and automated functions in the coming years. Sharing tasks and responsibilities creates the interesting challenge of transition of control of the vehicle between driver and automation. This paper presents research into this transition. By taking into account the attentiveness of the driver, different strategies were evaluated in a simulator study to create an optimal transition given the situation at hand. The study concentrates on an automated platoon system 'Virtual Tow Bar'. The results show that the differences among the tested conditions are small and no large trends are visible in either the subjective or the objective results. Hence it is concluded that the experiment should be repeated with a larger group naïve participants and probably more extreme parameter settings.

PAPERNO.15-0206-O

Safety Layer for Intelligent Transport Systems

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ABSTRACT
Intelligent Transport Systems are currently being developed in many different industry sectors.
These developments range from highly automated land vehicles, robots for mail delivery, agricultural drones up to ships automating vehicle ferry operations or automating the transportation of oil from the corresponding platforms.
Virtual drivers are a big challenge for implementation of these systems, and there is currently much activity in this area. But this is not the major challenge; which is making those systems safe and reliable. The following article shows an approach to realize safety and reliability of Intelligent Transport Systems by separating the functional components into a driver model with limited safety and reliability, and an additional safety layer.
In this approach, the driver model takes care of putting the required application case into practice and tries, similarly to a human driver, to continuously optimize the driving task. It is also possible to use training programs in productive operations for such driver models.
The driver model is supported by a static safety layer. This safety layer implements all safety targets that have been defined in the development phase and ensures that all safety targets are continuously being adhered to during the operation. This article shows an overview of the relevant safety targets for Intelligent Transport Systems and demonstrates strategies for implementing the security layer.

PAPERNO.15-0369-O

Intelligent Infrastructure + Vehicles to Address Transportation Problems

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ABSTRACT
Transportation systems around the world are showing signs of strain, and safety, congestion, and energy usage are significant societal problems. In the past, transportation professionals have attempted to solve these problems through largely "siloed" approaches focused on vehicle crashworthiness, infrastructure design, or energy efficiency. These separate approaches have succeeded, however, transportation problems continue to grow.

The University of Michigan has formed the Mobility Transformation Center (MTC) to create a consortium of industrial, government, and academic partners who comprise an ecosystem for enabling a future transportation system that leverages connected and automated technologies. This group has convened to define a potential ecosystem, identify and prioritize key research needs for enabling a holistic approach, identify key technology and policy hurdles with paths forward, identify business drivers and opportunities, as well as identify gaps in standards, testing, facilities, and risk management schemes. A key goal is to lay a foundation for, and demonstrate, a commercially viable connected and automated transportation system in Ann Arbor by 2021.

To achieve these goals, MTC is designing, building, and deploying significant test beds, facilities, and deployments so that real-world results can be incorporated into this process in a rapid fashion.

This paper presents a summary of current status and early results of this effort, to the extent that they are ready for dissemination. This includes a description of the role various industrial sectors may play in a future transportation system, as well as identified first-level research gaps.

Included is a high-level description of strengths and weaknesses of various technologies (vehicle sensors and communication, infrastructure sensors and communication, infrastructure operating systems, data systems, etc.) and their ability to address key transportation problems and opportunities.

Lastly, a summary of the current status of the physical test beds and deployments will be included.

The authors seek to further the discussion of the potential roles various transportation system components and industrial sectors, as well as the roles for government and academia. Additionally, the authors hope to generate meaningful discussion on the importance of a systems approach to solving key transportation problems, including proper technology planning, evaluation and deployment to ensure that results address the widest range of societal needs as possible.

PAPER NO. 15-0379-O

Development of a Basic Safety Message for Tractor-Trailers for Vehicle-To-Vehicle Communications

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ABSTRACT

Currently the Basic Safety Message (BSM) used by heavy truck tractor-trailers was developed for Vehicle-to-Vehicle (V2V) communications in the U.S. DOT Safety Pilot and uses a simplified bounding box algorithm for conveying the position and heading of the tractor-trailer. However, because of the articulated behavior inherent in a tractor-trailer, this approach does not accurately identify the trailer position or vehicle space for V2V safety applications in all situations. Consequently, in certain situations this can lead to an unacceptable number of false and missed warnings to drivers in surrounding connected vehicles. The U.S. DOT, in partnership with the Crash Avoidance Metrics Partnership (CAMP) and Mercedes-Benz Research & Development North America, Inc. (MBRDNA) conducted a project, Tractor-Trailer Basic Safety Message Development (TT-BSM), to develop technical solutions to this location identification problem for heavy truck tractors with one or more articulated trailers. TT-BSM developed several BSM enhancement approaches to more accurately represent tractor-trailer articulation. Furthermore, the team also completed the system and performance requirements and an assessment of the enhanced BSM impact on internal vehicle platform (On-Board Equipment, OBE, necessary vehicle sensors on the tractor and the trailer) and external systems (e.g. communications channel loading, other OBE-equipped vehicles, and backend systems). The enhanced BSM can more accurately transmit position and heading for articulated tractor-trailers and thus allows for better safety warnings and fewer false and missed warnings to drivers.

PAPERNO.15-0390-O

A Multiple Target Tracking Strategy using Moving Horizon Estimation Approach Aided by Road Constraint

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ABSTRACT

Tracking multiple road users is playing a significant role in autonomous vehicles and advanced driver assistance systems. Different from Multiple Target Tracking (MTT) in aerospace, the motion of the ground vehicles is likely constrained by their operational environment such as road and terrain. This information could be taken as additional domain knowledge and exploited in the development of tracking algorithms so as to enhance tracking quality and continuity. This paper proposes a new MTT strategy, Multiple Hypothesis Tracking using Moving Horizon Estimation approach (MHE-MHT), for tracking ground vehicles aided by road width constraints. In this strategy, tracking association ambiguity is handled by MHT algorithms which are proved as a preferred data association method for solving the data association problem arising in MTT. Unlike most of the MTT strategies, which solve target state estimation using Kalman filter (and its derivations), we propose a new solution using the moving horizon estimation (MHE) concept. By applying optimization based MHE, not only nonlinear dynamic systems but additional state constraints in target tracking problems such as road width can be naturally handled. The proposed MHE-MHT algorithm is demonstrated by a ground vehicle tracking scenario with an unknown and time varying number of targets observed in clutter environments. Using the optimal sub-pattern assignment metric, numerical results are presented to show the advantages of the constrained MHE-MHT structure by comparing it with the Kalman filter based MHT.

PAPERNO.15-0402-O

Probabilistic Prediction based Automated Driving Control in Urban Traffic Situation

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ABSTRACT

This paper represents an automated driving control algorithm in urban traffic situation. In order to achieve a development of a highly automated driving control algorithm in urban environments, the research issues can be classified into two things. One of the issues is to determine a safe driving envelope with the consideration of probable risks and the other is to achieve robustness of control performance under disturbances and model uncertainties. While human drivers maneuver a vehicle, they determine appropriate steering angle and acceleration based on the predictable trajectories of the surrounding vehicles. Therefore, not only current states of surrounding vehicles but also predictable behaviors of surrounding vehicles and potential obstacles should be considered in designing an automated driving control algorithm. In order to analyze the probabilistic behaviors of surrounding vehicles, we collected driving data on a real road. Then, in order to guarantee safety to the possible change of traffic situation surrounding the subject vehicle during a finite time-horizon, the safe driving envelope which describes the safe driving condition over a finite time horizon is defined in consideration of probabilistic prediction of future positions of surrounding vehicles and potential obstacles. Since an automated driving control algorithm is required to operate in a wide operating region and limit the set of permissible states and inputs, a model predictive control (MPC) approach has been used widely in designing an automated driving control algorithm. MPC approach uses a dynamic model of the vehicle to predict the future states of the system and determines optimal control sequences at each time step to minimize a performance index while satisfying constraints based on the predicted future states. Since the solving nonlinear optimization problem has computational burden, we design an architecture which decides a desired steering angle and longitudinal

acceleration parallel to reduce the computational load. For the guarantee of the robustness of control performance, a robust invariant set is used to ensure robust satisfaction of vehicle states and constraints against disturbances and model uncertainties. The effectiveness of the proposed control algorithm is evaluated by comparing between human driver data and proposed algorithm.

PAPERNO.15-0428-O

Human Factors Evaluation of Level 2 and Level 3 Automated Concepts

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ABSTRACT

This project evaluates how drivers interact with different automated vehicle functions under various concepts of Level 2 and Level 3 automation. The objective is to determine whether principles for human-machine interface (HMI) design for automated vehicles could be based on things such as timing, sequence, and presentation of automated functions produced by this study. Methods involve test track evaluations of participants using three distinct automation concepts, two involving automation Level 2 and one involving automation Level 3 (as defined by the National Highway Traffic Safety Administration [NHTSA] policy paper on vehicle automation; NHTSA, 2013). Data sources included both objective and subjective data from participants' responses to the different portions of the experimental protocols. Results will be produced from parametric linear regression analyses and qualitative evaluations of participants' subjective responses to questionnaires. Where appropriate, statistical techniques will be applied for conditioning the sample data, to ensure that the assumptions underlying these analyses are met. The detailed timing, sequence, and presentation measurements from the various research efforts involved herein will be used to specify human factors design principles for automated vehicle HMIs. The resulting principles would benefit from subsequent naturalistic evaluations for fine-tuning the performance metrics, and for addressing any gaps or new questions arising from this research. Crash avoidance technologies are evolving rapidly toward increasing automation, involving a higher complexity of interoperability between user and vehicle functions than what has previously been known. Understanding the detailed human factors capabilities and limitations of these users and the impacts of the timing, sequence, and presentation of information presented to the users will be important for shaping the safety policies.

PAPERNO.15-0431-O

Improve Road Safety using Combined V2V and Pre-Collision Systems

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ABSTRACT

In current vehicle to vehicle (V2V) communication systems, each vehicle broadcasts its motion status and receives information from other vehicles in order to make safety decisions and actions. State-of-the-art pre-collision systems (PCS) utilize onboard sensors to collect potential crash object information for making safety action decisions. This V2V-PCS combination enables a vehicle to not only send its own motion information, but also its PCS detected information to other vehicles. Conceptually, the additional information should help a V2V enabled vehicle make its safety related decisions more accurately and efficiently. The objective of this study is to find if a combined V2V and PCS system (V2V-PCS) can further improve the safety of not only V2V-PCS enabled vehicles but also other non V2V-PCS enabled vehicles on the road. This paper describes a process that can be used to analyze pedestrian and vehicle scenarios, and determine whether or not the safety of pedestrians could be improved by a V2V-PCS system. It also gives an analytical method for determining the benefit of using V2V-PCS. The environments set up for V2V-PCS simulation and real vehicle testing are also described.

PAPERNO.15-0447-O

Safety 2.0 – Potentials of Cooperative Safety by Vehicle-To-X Communication

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ABSTRACT

Safety Technology has evolved significantly over the last decades. The technological progress, based on the continuous advances in vehicle crash worthiness, restraint systems and active safety functions have made traffic safer than ever before. Latest development has led to a sharp increase in the equipment rates for advanced surrounding sensors, so that on-board surrounding sensors such as camera, radar and lidar sensors have become standard equipment in modern vehicles.

Surrounding sensors can provide safety critical information to a vehicle and are thus a pre-requisite for new integrated safety functions such as Forward Collision Warning (FCW) or Emergency Brake Assist (EBA). What if vehicles could communicate with each other and create a network for safety critical information in traffic? What if my vehicle gets real-time information on sudden braking maneuvers 500 meters ahead? What if a vehicle camera detects a cyclist approaching at an urban intersection and shares the cyclist position information with other vehicles? What if vehicles share their mass, velocity and position before a crash to optimize the strategy of airbag deployment? Wouldn`t all this open a new dimension of safety in future traffic – Safety 2.0?

This paper promotes cooperative safety as a new approach based on the exchange of safety critical information in traffic. The underlying thesis is that cooperative safety would dramatically increase the safety for a large number of traffic participants, including vehicles without on-board surrounding sensors and vulnerable road users (VRUs) like children, pedestrians and cyclists.

PAPERNO.15-0451-O

Key Considerations in the Development of Driving Automation Systems

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ABSTRACT

The historical roles of drivers, vehicle manufacturers, federal and state regulators, and law enforcement agencies in automotive safety is well understood. However, the increasing deployment of driving automation technologies to support various comfort, convenience, efficiency, productivity, mobility, and possibly safety features has the potential to alter this understanding. In order to facilitate clarity in discussing the topic of driving automation with other stakeholders and to clarify the level(s) of automation on which the agency is currently focusing its efforts, the National

Highway Traffic Safety Administration (NHTSA) released a Preliminary Statement of Policy (SOP) concerning Automated Vehicles that included its automation levels.
In this paper, we present key factors for consideration in each automation level which are based upon SAE J3016. These factors focus on adding more specificity with regard to the distribution of the driving tasks between the driver and the automation system. The result of this effort has led to a refinement of our understanding of the automation levels based on the nature of the vehicle control aspect provided by the feature, the nature of the environmental sensing and response, the fallback strategy employed, and the feature's scope of operation.

PAPERNO.15-0454-O

An Overview of NHTSA's Electronic Reliability and Cybersecurity Research Programs

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ABSTRACT

This paper provides an overview of the National Highway Traffic Safety Administration's (NHTSA) research programs in electronic control systems reliability and automotive cybersecurity. The agency's electronics reliability research covers methods and voluntary standards both inside and outside the automotive industry. The research looks for such standards and methods that assess, identify, and mitigate potential new hazards that may arise from the increasing use of electronics and electronic control systems in the design of modern automobiles. Cybersecurity, within the context of road vehicles, is the protection of vehicular electronic systems, communication networks, control algorithms, software, users, and underlying data from malicious attacks, damage, unauthorized access, or manipulation.

PAPERNO.15-0457-O

Analysis of Vehicle-Based Security Operations

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ABSTRACT

Vehicle-to-vehicle (V2V) communications promises to increase roadway safety by providing each vehicle with 360 degree situational awareness of other vehicles in proximity, and by complementing onboard sensors such as radar or camera in detecting imminent crash scenarios. In the United States, approximately three hundred million automobiles could participate in a fully deployed V2V system if Dedicated Short-Range Communication (DSRC) device use becomes mandatory. The system's reliance on continuous communication, however, provides a potential means for unscrupulous persons to transmit false data in an attempt to cause crashes, create traffic congestion, or simply render the system useless. V2V communications must be highly scalable while retaining robust security and privacy preserving features to meet the intra-vehicle and vehicle-to-infrastructure communication requirements for a growing vehicle population.
Oakridge National Research Laboratory is investigating a Vehicle-Based Security System (VBSS) to provide security and privacy for a fully deployed V2V and V2I system. In the VBSS an On-board Unit (OBU) generates short-term certificates and signs Basic Safety Messages (BSM) to preserve privacy and enhance security. This work outlines a potential VBSS structure and its operational concepts; it examines how a vehicle-based system might feasibly provide security and privacy, highlights remaining challenges, and explores potential mitigations to address those challenges.
Certificate management alternatives that attempt to meet V2V security and privacy requirements have been examined previously by the research community including privacy-preserving group certificates, shared certificates, and functional encryption. Due to real-world operational constraints, adopting one of these approaches for VBSS V2V communication is difficult. Timely misbehavior detection and revocation are still open problems for any V2V system. We explore the alternative approaches that may be applicable to a VBSS, and suggest some additional research directions in order to find a practical solution that appropriately addresses security and privacy.

PAPER NO. 15-0210-O

An Analysis of Hybrid and Electric Vehicle Crashes in the U.S.

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ABSTRACT

The growing popularity of hybrids and electric vehicles in the U.S. has raised questions about whether they might pose a different crash risk than conventional vehicles. In particular, there have been anecdotal reports of fires associated with the battery system in these advanced fuel vehicles. The objective of the study was to characterize the factors that influence the risk of serious to fatal injury in U.S. hybrid and electric passenger vehicle crashes.

Our approach in this study was to compare the crash performance of the conventional passenger vehicle fleet with hybrid/electric passenger vehicles in the U.S. The study was based upon the analysis of three U.S. crash databases: the Fatal Analysis Reporting System (FARS), the National Automotive Sampling System / Crashworthiness Data System (NASS/CDS), and the National Automotive Sampling System / General Estimates System (NASS/GES). Cases recorded by the databases between the years 1999 and 2013, and involving passenger vehicles model year 2000 and newer were extracted from all three databases.

Hybrid vehicles constituted less than 1% of the total vehicle population in all three databases. FARS contained no fatalities in electric vehicles, and less than 0.01 % of cases in NASS/CDS and NASS/GES involved electric vehicles.

The incidence of fire was lower for hybrid vehicles than the conventional fleet in all three databases. Fatal crashes involving fire constituted 2.6% of hybrid vehicle cases and 4.4% of conventional vehicle cases. No cases of fire or electric shock injury associated with hybrid vehicles were found in NASS/CDS. Only 1 case of a hybrid fire was found in NASS/GES and 5 cases of hybrid fire were found in FARS. No fires involving electric vehicles were found in any of the three databases.

Similar crash characteristics were found for both hybrid and conventional vehicle populations. Median longitudinal delta-V was 18 km/hr for hybrid vehicles and 14 km/hr for conventional vehicles. Hybrid vehicle occupants were found to have higher risk of AIS2+ upper extremity injury but lower risk of AIS2+ lower extremity injury than conventional vehicle occupants. Similar risk of AIS2+ head and chest injury was observed between the two groups.

The most notable difference between hybrid vehicles and conventional passenger-vehicles was that occupants of hybrid vehicle were more likely to be older than occupants of conventional vehicles. In FARS, the median age of fatally injured hybrid vehicle occupants was 59 years versus 36 years for conventional vehicle occupants. In NASS/CDS, the median age of hybrid vehicle occupants was 42 years and the median age of conventional vehicle occupants was 29 yrs. In NASS/GES, the median age of hybrid/electric vehicle occupants was 44 years, as compared to the median age of 32 years for conventional vehicle occupants.

The present study characterized the crash and occupants of hybrid and electric vehicles. The comparison between hybrid and conventional vehicle crashes showed little difference in the crash performance and injury outcome between the two groups. The incidence of fire was actually lower in hybrid vehicles than in the rest of the fleet.

PEER REVIEW: PAPERNO.15-0164-O

Fire Tests on E-Vehicle Battery Cells and Packs

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ABSTRACT

Research Question/Objective

Thermal abuse is a key failure pathway for Li ion batteries. Gases emitted during a thermal event contain a variety of flammable and toxic constituents. The Swedish Civil Contingencies Agency (MSB) initiated a research project called E-Vehicle Safe Rescue together with industry and academic partners to investigate effects of abuse conditions on Li ion battery systems and develop guidelines regarding safe handling of e-vehicles in road accidents. The present work is an in-depth analysis of parameters affecting the Li ion energy storage system exposed to external fire.

Methods and Data Sources

Two types of Li ion pouch cells designed for e-vehicles with similar physical dimensions but different electrical capacity were studied: 7 Ah LFP (LiFePO4) and 14 Ah NMC (Li(Ni1/3Mn1/3Co1/3)O2). Samples included single cells, multiple cell assemblies and one complete NMC e-vehicle battery pack.

Single Burning Item (SBI) equipment was used for bonfire tests. Multiple cell assemblies were placed so that only the first cell was directly exposed to the flame. Heat release rate (HRR) and heat energy generated were quantified by oxygen consumption calorimetry. Gas analysis was done by Fourier Transform Infrared Spectroscopy (FTIR). Weight loss was measured in order to provide a baseline for comparison between cells.

Results

The total amount of energy released from the battery was independent of the state of charge (SOC) while the heat release rate (HRR) depended on SOC, the number of cell and on cell chemistry. NMC cells release energy faster than LFP cells. Medium-high SOC resulted in higher HRR than low SOC, but the relationship was not linear.

The LFP batteries emitted more hydrogen fluoride (HF) than the NMC batteries. The HF amount released increased with the number of cells and increasing SOC although relationships were not linear.

The internal temperature of the complete NMC pack stayed at about 300-350 ◦C and the battery continued to generate fumes for hours following fire quenching.

Discussion and Limitations

An explanation why relative amounts of toxic emission per cell increased with the number of cells is that highly reactive HF and intermediary PF5 could accumulate before venting in cells not directly exposed to fire while the bottom cell acted as thermal shield.

NMC cells showed significantly faster HRR than LFP cells but the difference in the total energy released per cell was small. Consequently the energy released per Ah was double for LFP cells compared to NMC. This may be explained by volumetric similarities between cells despite the different capacities, and hence comparable amounts of electrolyte, the main contributor of heat energy.

Only one cell geometry (i.e. pouch cells) was tested and hence results may differ depending on cell design.

Conclusion and Relevance to session submitted

Energy storage system configuration and size play greater roles in determining abuse response than total amount of electric energy stored in the cells at the time of failure. Safety characteristics must be evaluated on a system level in order to have a fair comparison with conventional vehicles since single cell data may exaggerate risks with Li ion batteries.

PAPERNO.15-0073-O

Thermal Modelling of Fire Propagation in Lithium-Ion Batteries

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ABSTRACT

The objective of the present work is to assess the risk of spreading of fire between Lithium-ion battery cells initiated by a thermal runaway. In particular it aims at developing means to predict the temperature of cells in the vicinity of an overheated cell during the first 5-7 minutes after the thermal event in a Li-ion cell that has an organic based electrolyte which is flammable. Finite-Element (FE) modelling is used to compute the heat transfer between cells. The spreading model is assessed modeling a scenario where the cells are exposed to a 15 kW propane burner. Two different models where utilized, one that considers the conjugate heat transfer between the surrounding hot gases and the battery cells while the second is a thermal model where the boundary conditions are measured in a mock-up test. The results from the two models are contrasted to experimental data where the heat release rate (HRR) is utilized as an input to the simulation. It is found that the temperature increase in a neighboring cell can be quantitatively estimated in certain cases during the early stages of the fire taking into account the anisotropic thermal conductivity of the cells using the conjugate heat transfer model. Moreover, the thermal model captures the qualitative behavior of the test results. However, the temperature increase is slower in the computational model.

PAPERNO.15-0234-O

Protection of Lithium-Ion Traction Batteries in the Electric Car

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ABSTRACT

The storage elements in an electric vehicle (EV) remain a key challenge to wide-scale, successful deployment of EVs that are appealing to customers and are adequately functional (e.g. in terms of range and drivability). State-of-the-art electric storage systems are lithium-ion batteries, offering approximately 0.5 km driving range per 1 kg of battery pack mass (see Funcke et al [1]). However, these battery packs require high level safety measures to avoid e.g. mechanical damage of the cells, which increases the pack mass again. In order to make a reliable statement about the battery safety at an early stage of development, detailed knowledge of the mechanical behavior of the cells as well as its reproduction in the virtual development process is necessary.
Based on a sample design of a main battery structure, the development process of the cell model is explained. The first steps are the integration of the design in a full vehicle and the determination of the dominant cell deformations, which are transferred to cell load cases. These mechanical abuse tests of cells deliver the input data for generating an adequate finite-element (FE) model, which offers the opportunity to dimension the battery pack and to add safety measures. With this simulation model inflatable structures as well as passive reinforcements for the traction battery are investigated.
To validate the simulation results, component tests on system level, i.e. complete battery packs, are conducted. The test is based on the full vehicle reference design load case, in this case the EuroNCAP pole side impact with a modified pole position and an impact velocity of 50 km/h. An analysis of the impact position is needed since the vulnerability to intrusion of the battery pack and the stiffness of the vehicle structure varies along the vehicle longitudinal axis.
These component tests confirm the simulation results and show the potential of inflatable structures and passive protection systems. Furthermore, it is possible to generate a FE model for lithium-ion batteries, which is applicable to full vehicle simulations.
Although it is possible to map the mechanical characteristics to the generated cell model, this model is limited to the investigated load cases, which have been the result of the battery position within the vehicle and the corresponding critical design load case. Since the battery may be placed in another position within the vehicle and the arrangement of the cells may change, the cell model is not universal. However, it is extensible to other load cases.
Overall, the results from the study with the inflatable elements show clearly the benefit of those structures. With low additional mass a high positive effect (e.g. lower intrusion) is achieved, which means the ratio of the incorporated mass to the reached protective effect is lower than with passive protection systems.

PAPERNO.15-0163-O

E-Vehicle Safety – Pyro Switch as High Voltage Circuit Breaker & Bypass

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ABSTRACT

An E-Vehicle (i.e. electrified vehicle such as EV and HEV) is often equipped with a traction battery with voltage of as high as 200 to 600 Volt dc. It is critical that such voltage shall not be put in circuiting contact with any person at any point – workshop, crash or post-crash rescue. NHTSA have defined testing procedures in FMVSS 305 so as to assure that a basic level of safe guard systems shall be utilized by conventional E-Vehicles. The paragraph S5.3 (b) demands that the traction battery shall present an external voltage <60 Volt dc after crash. This is commonly solved with relays and melting fuses which have their Pros and Cons. Relays/contactors have the benefit of being a reversible active component but are limited to operative currents and are prone to switching bounces and they are relatively heavy, large and expensive. A melting fuse is a passive component that can operate at extreme currents but is irreversible and their cutting speed is dependent on the magnitude of the fault-current.

In this paper Autoliv will present a methodology on how to disconnect a faulty battery unit rapidly (in milliseconds) regardless of the magnitude of the fault-current. This methodology can also be used to divide a traction battery down to

minor units of <60 Volt dc or even bypass and disconnect a faulty battery module with maintained power electronics in order to retain mobility as well as adding the option of discharge the disconnected module so as to prevent stranded energy.

Autoliv has investigated how to use pyrotechnic switches for disruption of over-currents in a traction system with battery packs of about 300-400 Volt dc. Those tests, aiming at safe disconnection without lasting arcs, included static faulty-current tests and tests simulating an E-Vehicle traveling 50-70 km/h on a horizontal surface. Autoliv's Pyro Safety Switch (PSS) arrangement proved capable to safely disconnect both a complete battery pack (ranging from 300 to 400 Volt dc) and the intended battery module (30-60 Volt dc) in less than 0.5 milliseconds.

PAPERNO.15-0252-O

A Partnership between Renault and French First Responders to Ensure Safe Intervention on Crash or Fire-Damaged Electrical Vehicles

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ABSTRACT

In order to ensure first Responder safety, Renault set up a collaborative approach to involve rescuers in our electrical vehicle conception. The breakthrough came from the integration of crash and fire deterioration from the earliest stages of vehicle development.

Collaboration with fire brigades revealed 5 key areas which were then dealt with: electrical vehicle identification; prevention of electrical risk during emergency intervention; the impact of Li Ion batteries on occupant extrication and fire; co-creation of decision-making tools (Emergency Response Guide or ERG, rescue cards); training sessions on electrical vehicles.

EV prototypes were provided to study how the 400V system affected fire brigade intervention. Extrication tests were led on the full range of Renault electrical vehicles to take into account the different locations of the 400V battery. Fire tests were carried out until total combustion of the 400V batteries was reached. Then, extinction tests in open and closed environments were conducted, led by French scientific laboratories. Temperatures, thermal radiation, and concentrations of flue gases effluents were measured in most of these tests.

A large number of electrical vehicles were donated to French and European fire brigades for extrication training and fire demonstration. Bespoke electrical vehicles were produced as training supports and offered to fire brigades.

Trainings are given for free to French rescuers all around the year by an engineer from Renault, expert in electrical vehicle interventions. Finally, Renault regularly participates in national working groups with fire brigades and contributes to the ISO initiative on ERG writing and templates.

This combination of actions and results removed doubts as to the safety of electrical vehicle 400V batteries in a deteriorated state; enabled the proposal of a modus operandi for fire brigade intervention; led to the modification of the architecture of the 400V battery casing and the vehicle itself to improve rescuer intervention; highlighted the need to standardize service plug location across the range of Renault electrical vehicles.

Thanks to this fruitful collaboration between Renault and French fire brigades, rescuers acquired knowledge and skills for intervention on Li Ion battery electrical vehicles.

PAPERNO.15-0361-O

Recommendations for the Safe Handling of Damaged Electric Vehicles after Severe Road Traffic Accidents

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ABSTRACT
The EVERSAFE project addressed many safety issues for electric vehicles including the crash and post-crash safety. The project reviewed the market shares of full electric and hybrid vehicles, latest road traffic accident data involving severely damaged electric vehicles in Europe, and identified critical scenarios that may be particular for electric vehicles. Also, recent results from international research on the safety of electric vehicles were included in this paper such as results from performed experimental abuse cell and vehicle crash tests (incl. non-standardized tests with the Mitsubishi i-MiEV and the BMW i3), from discussions in the UN IG REESS and the GTR EVS as well as guidelines (handling procedures) for fire brigades from Germany, Sweden and the United States of America. Potential hazards that might arise from damaged electric vehicles after severe traffic accidents are an emerging issue for modern vehicles and were summarized from the perspective of different national approaches and discussed from the practical view of fire fighters. Recent rescue guidelines were reviewed and used as the basis for a newly developed rescue procedure. The paper gives recommendations in particular towards fire fighters, but also to vehicle manufacturers and first-aiders.

PAPERNO.15-0047-O

Evaluation of Measurement Procedure for Post-Crash Hydrogen Concentration

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ABSTRACT
To examine the measurement method for post-crash hydrogen or helium concentrations in the cabins and other enclosed spaces of vehicles which is provided in the UN Global Technical Regulation on hydrogen fuel cell vehicles (HFCV-gtr), the present study investigated 1) wind velocity conditions not affecting the hydrogen concentrations in the cabin, 2) the effect of the impact absorber of a moving deformable barrier, and 3) the feasibility of substituting the hydrogen concentration measurement with helium gas. The results indicated that the HFCV-gtr measurement method posed problems in its accuracy and reliability because hydrogen concentrations in the cabin varied under the influence of a 0.1 m/s wind and in the presence of an impact absorber in contact with the test vehicle. Furthermore it was found that although HFCV-gtr defines a permissible hydrogen concentration of 4vol% to be equivalent with a permissible helium concentration of 3vol%, this equivalence could not be verified. Consequently it is necessary to replace the HFCV-gtr measurement method for in-cabin hydrogen concentrations with a simpler method immune to external disturbances.

PAPERNO.15-0326-O

Failure Analysis of Compressed Natural Gas Containers for Automotive Use

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ABSTRACT
In 2009, the National Highway Traffic Safety Administration's (NHTSA's) Office of Defects Investigation made site visits to two different companies that utilized compressed natural gas (CNG) to fuel their vehicle fleets. The purpose of these site visits was to obtain information concerning two independent incidents where high pressure CNG fuel containers on fleet vehicles ruptured during or shortly after refueling. These containers were represented as conforming to industry standard ANSI/NGV2 [1], and were still within their 15 year manufacturer recommended service life (although they had experienced several years of on-road use). Further, the newer model containers were self-certified by the manufacturer as compliant with Federal Motor Vehicle Safety Standard (FMVSS) 304 [2].

After the container ruptures occurred, each of the companies, for reasons of safety, retired the sister vehicles in their fleets. The decommissioning of these fleets offered an opportunity to NHTSA to obtain some of the retired CNG containers, which experienced similar service conditions to those that ruptured during refueling, and to subject them to both nondestructive (NDE) and destructive evaluation (DE) to document in-service wear, damage and residual life.
To this end, NHTSA entered into an Interagency Agreement with the National Aeronautics and Space Administration (NASA) White Sands Test Facility (WSTF), to conduct the evaluation of the used containers and compare them to unused containers of similar design. NASA has been performing test and evaluation of composite pressure vessels, similar to those designed for automotive use, since 1978. The objective of the evaluation is to gain valuable insight into the construction and deterioration elements that could suggest potential improvements in the existing standards.
Destructive and nondestructive evaluation of the aged and new containers is on-going. This paper presents the results of the evaluation to date and potential future steps in the program.

PAPERNO.15-0405-O

General Virtual Testing Methodology for Type IV CNG Tanks

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ABSTRACT

The project MATISSE funded by European Commission's 7th Framework Programme (FP7) aims to make a significant step forward in the capability of the automotive industry to model, predict and optimise the crash behaviour of mass produced fibre reinforced polymers (FRP) with the focus set on components for alternatively powered vehicles (APV). One of the project's main research goals is the development of a general virtual testing methodology (VTM) for the development of APV driven by compressed natural gas (CNG) equipped with composite FRP tanks of Type IV.
Due to the increasing legislative demands on the emission of future vehicles, the development of APVs that are in this regard superior to conventional internal-combustion engines (ICE) driven by petrol or diesel fuel is currently in the centre of attention of the automotive industry. Here, the usage of ICE with CNG supply offers advantages in comparison to other concepts, since it requires only moderate modifications of the conventional drive train. Because of the high mechanical demands on the required high-pressure storage tanks and the need for lightweight structures, which also contributes to the emission reduction, the usage of material of high specific material properties is required. Especially the full composite tanks of the Type IV show a high potential in this regard. Since these high-pressure storage components form a significant safety hazard, the accurate analysis of the mechanical demands during relevant crash load cases is of great importance. For the proper and optimal integration of the tanks into the vehicle during the APV design and development process at industrial level, moreover the predictability of the material and component behaviour using the finite element method (FEM) is indispensable.
Within the MATISSE project a new overall approach for the crash analysis of CNG tanks is proposed. This paper describes the main aspects of this VTM:
First, a FRP material modelling approach for wet wound CNG tanks, that makes use of the so-called "reverse FEM" as well as of novel physically based material models that are fed with calculative as well as literature based material values and are validated on three point bending tests of wound tubes was defined.
Then, the derived material models for glass and carbon fibre were subsequently used for the modelling of FEM tank models, whereby different steps of optimisation of on the one hand the accuracy and on the other hand the simulation time were conducted.
In a next step, different relevant load cases on a full vehicle model of a compact car equipped with a CNG tank where simulated and analysed. The detected highest mechanical demands were thereupon transferred to a component test programme on a tank-subsystem that depicts the loads obtained by the tanks. Here again, the FEM model of the tank is used to find the appropriate boundary conditions.
The developed test programme was subsequently conducted on a series of physical tanks and the simulation approach and thus the VTM was validated on the results.

Consumer Information Approaches To Improve Global Safety

Wednesday, June 10, 2015 | 2:00 p.m.- 6:00 p.m.
Chairperson: Andre Seeck, Germany|
Co-Chair: David Ward, United Kingdom|
TRACK C | Room: F1-F2

PEER REVIEW: PAPERNO.15-0049-O

Occurrence of Serious Injury in Real-World Side Impacts of Vehicles with Good Side-Impact Protection Ratings

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ABSTRACT

Research Question/Objective

The Insurance Institute for Highway Safety (IIHS) introduced its side impact consumer information test program in 2003. The barrier used in the test was developed to represent midsize LTV designs based on the increasing numbers of LTVs in the fleet and of side-impact fatalities for occupants of vehicles struck by LTVs. The barrier is taller than that used in regulatory testing and in the National Highway Traffic Safety Administration's New Car Assessment Program (NCAP). Only 18 percent of 2004 model year vehicles achieved good ratings in the IIHS test. Since that time, side airbags and structural improvements have been implemented across the fleet and the proportion of good ratings has increased to 96 percent of 2014 model year vehicles. Research has shown that drivers of good-rated vehicles are 70 percent less likely to die in a left-side crash than drivers of poor-rated vehicles. Despite these improvements, side impact fatalities accounted for about one-quarter of passenger vehicle occupant fatalities in 2012. This study is a detailed analysis of real-world cases with serious injury resulting from side crashes of vehicles with good ratings in the IIHS side impact test.

Methods and Data Sources

NASS-CDS and CIREN were queried for occupants of good-rated vehicles who sustained an AIS≥3 injury in a side-impact crash. The resulting 110 cases were categorized by impact configuration and other factors that contributed to injury. Patterns of impact configuration, restraint performance, and occupant injury were identified and discussed in the context of potential upgrades to the current IIHS side impact test.

Results

Three-quarters of the injured occupants were involved in near-side impacts. For these occupants, the most common factors contributing to injury were crash severities greater than the IIHS test (38%), inadequate side-airbag performance (36%), and lack of side airbag coverage for the injured body region (20%). In the cases where an airbag was present but did not prevent the injury, occupants were often elderly and exposed to oblique loading. Around 40% of the far-side occupants were injured from contact with the struck-side interior structure, and almost all of these cases were more severe than the IIHS test. The remaining far-side occupants were mostly elderly and sustained injury from the center console, instrument panel, or seatbelt. In addition, many far-side occupants were likely out of position due to events preceding the side impact.

Discussion and Limitations

Individual changes to the IIHS side impact test have the potential to reduce the number of serious injuries in real-world crashes. These include impacting the vehicle farther forward and/or obliquely (relevant to 27% of all cases studied), greater test severity (16%), the inclusion of far-side occupants (9%), and more restrictive injury criteria (8%).

Combinations of these changes could be more effective. The study is limited by the sample size and the lack of information on crash exposure. While side-impact regulation and NCAP changes introduced in 2010 may address some of these issues, too few vehicles in the study met these criteria to draw conclusions.

Conclusion and Relevance to session submitted
The study identifies potential upgrades to side impact consumer information testing.

PEER REVIEW: PAPERNO.15-0093-O

Development of a Methodology for Assessment of Integrated Pedestrian Protection Systems with Pre-Crash Braking and Passive Safety Components

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ABSTRACT

Research Question/Objective
Autonomous Emergency Braking (AEB) systems for pedestrians have been predicted to offer substantial benefit. On this basis, consumer rating programmes, e.g. Euro NCAP, are developing rating schemes to encourage fitment of these systems. One of the questions that needs to be answered to do this fully, is to determine how the assessment of the speed reduction offered by the AEB is integrated with the current assessment of the passive safety for mitigation of pedestrian injury. Ideally, this should be done on a benefit related basis.

The objective of this research was to develop a benefit based methodology for assessment of integrated pedestrian protection systems with pre-crash braking and passive safety components.

Methods and Data Sources
A methodology has been developed which calculates the cost of pedestrian injury expected, assuming all pedestrians in the target population (i.e. pedestrians impacted by the front of a passenger car) are impacted by the car being assessed, taking into account the impact speed reduction offered by the car's AEB (if fitted) and the passive safety protection offered by the car's frontal structure. For rating purposes, this cost can be normalised by comparing it to the cost calculated for selected cars.

The methodology uses the speed reductions measured in AEB tests to determine the speed at which each casualty in the target population will be impacted. The injury to each casualty is then calculated using the results from standard Euro NCAP pedestrian impactor tests and injury risk curves. This injury is converted into cost using 'Harm' type costs for the body regions tested. These costs are weighted and summed. Weighting factors were determined using accident data from Germany and GB and the results of a benefit analysis performed by the EU FP7 AsPeCSS project. This resulted in German and GB versions of the methodology.

Results
The methodology was used to assess cars with good, average and poor Euro NCAP pedestrian ratings, with and without a current AEB system fitted. It was found that the decrease in casualty injury cost achieved by fitting an AEB system was approximately equivalent to that achieved by increasing the passive safety rating from poor to average. Also, it was

found that the assessment was influenced strongly by the level of head protection offered in the scuttle and windscreen area because this is where head impact occurs for a large proportion of casualties.

Discussion and Limitations
The major limitation within the methodology is the assumption used implicitly during weighting. This is that the cost of casualty injuries to body areas, such as the thorax, not assessed by the headform and legform impactors, and other casualty injuries such as those caused by ground impact, are related linearly to the cost of casualty injuries assessed by the impactors.

Conclusion and Relevance to session submitted
A methodology for assessment of integrated pedestrian protection systems was developed.

This methodology is of interest to consumer rating programmes which wish to include assessment of these systems. It also raises the interesting issue if the head impact test area should be weighted to reflect better real-world benefit.

PAPERNO.15-0228-O

Consumer Safety-Information Programs at IIHS

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ABSTRACT
Since 1969, when the Insurance Institute for Highway Safety (IIHS) began publishing results of low-speed crash tests to highlight differences in vehicle bumpers, it has been a significant source of information about how the safety of different vehicle designs varies. Currently, IIHS maintains crashworthiness ratings covering five crash modes along with ratings of front crash prevention (FCP) systems and children's booster seats, as well as annual updates of insurance loss reports from its affiliate, the Highway Loss Data Institute (HLDI).
This report describes the experience with IIHS's latest consumer information efforts and identifies the next areas of consumer information to come online. It presents information about the number of vehicle models and booster seats evaluated; their ratings assigned as well as media, consumer, and manufacturer response; and small overlap crashworthiness and FCP ratings. Research underpinning future rating programs addressing Lower Anchors and Tethers for Children (LATCH) and advanced head lighting systems also is summarized.
Since launching its booster seat ratings, IIHS has evaluated 200 designs for their ability to adjust rear seat belt fit to booster-age children across a wide variety of rear seat belt configurations. The number of models rated Best Bet, indicating they will provide good belt fit in common passenger vehicles, has increased from a low of 10 in 2008 to 69 in 2014. Media coverage of these annual ratings announcements is estimated to average an audience of 88 million people in the United States. IIHS internet pages with booster ratings are among the most viewed, with an average of 102,800 page views monthly.
IIHS began rating vehicle front crashworthiness on the basis of a 64 km/h small overlap crash against a rigid barrier in 2012. Of the 118 currently rated 2015 models, 49 are good, 25 acceptable, 23 marginal, and 21 poor. Several models have been tested in two design iterations with improved performance in the second test, indicating automakers are able to design vehicles to better protect occupants in similar crashes. It is estimated that the media coverage across all small overlap ratings announcements has achieved 1.1 billion views. Surveys of automobile dealers indicate that good ratings in this test have led to increased sales, at least in the short term.
IIHS ratings of vehicle FCP systems include both warning and auto braking functions. The proportion of new models available with FCP of any kind has increased from 30 to 60 percent. The combined media coverage of three announcements featuring FCP ratings were viewed 212 million times. While not as strong as for crash test ratings, there was indication that these announcements positively affected sales of vehicles with these systems.
Large audiences for IIHS consumer information programs have prompted manufacturers of rated products to make changes in ways indicated by IIHS tests. Based on this experience with current programs, there is good reason to believe that IIHS ratings of LATCH and advanced head lighting systems can also improve vehicle safety.

PAPERNO.15-0239-O

Predicting the Impact of Vehicle Safety Developments in Emerging Markets Following the Industrialized Countries' Experience

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ABSTRACT
By taking the vehicle safety development experience witnessed in the EU and applying it to the situation in an emerging market, this work quantifies the casualty reduction potential could be a saving of between 1,200 and 4,300 Malaysian fatalities by 2030.

PAPERNO.15-0258-O

Beyond Safety Legislation: Contribution of Consumer Information Programmes to Enhanced Injury Mitigation of Pedestrians during Accidents with Motor Vehicles

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ABSTRACT
During the past five years, a Euro NCAP technical working group on pedestrian safety has been working on improving test and assessment procedures for enhanced passive pedestrian safety.

After harmonizing the tools and procedures as much as possible with legislation, the work was mainly focused on the development of grid procedures for the pedestrian body regions head, upper leg with pelvis and lower leg with knee. Furthermore, the test parameters for the head and the upper leg were revised, a new lower legform impactor was introduced and the injury thresholds were adjusted or, where necessary, the injury criteria were changed. Finally, the assessment limits and colour scheme were refined, widening the range and adding two more colours in order to provide a more detailed description of the pedestrian safety performance.

By abstaining from an assessment based on a worst point selection philosophy, the improved test point determination procedures that were introduced during the years 2013 and 2014 give a more homogeneous, high resolution picture of the pedestrian safety performance of the vehicle frontends. By using a uniform grid for each test zone approximately 200 test points, evenly distributed within each area, can now be assessed per vehicle.
The introduction of the flexible pedestrian legform impactor in 2014 enables a more realistic injury prediction of the knee and the tibia using a biofidelic test tool.

With the new upper legform test that has been launched in 2015 the assessment in that area is now focusing on the injured body region instead of the injury causing vehicle part and thus is aligned with the approach in the remaining body regions head and lower leg. At the same time, a monitoring test with the headform impactor against the bonnet leading edge is closing the possible gap between the test areas to identify injury causing vehicle parts that moved out of focus due to the introduction of the new upper legform test.

The paper describes the new test and assessment procedures with their underlying philosophy and gives an outlook in terms of open issues, specifying the needs for further improvement in the future.

In parallel to the work of the pedestrian subgroup, a Euro NCAP working group on heavy vehicles introduced a set of protocol changes in 2011 that were related to the assessment of M1 vehicles derived from commercial vehicles, with a gross vehicle weight between 2.5 and 3.5 tons and 8 or 9 seats. The paper also investigates the applicability of the new pedestrian test and assessment procedures to heavy vehicles.

PAPER NO. 15-0267-O

Evaluation of the Euro NCAP Whiplash Protocol Using Real-World Crash Data

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ABSTRACT

Whiplash injuries account for the vast majority of casualties in road traffic crashes, leading to long-term consequences. The majority occur in rear-ends crashes. Consumer crash tests play an important role in promoting effective concepts to reduce the problem. The current Euro NCAP whiplash test protocol includes three sled tests at varying impact speeds and pulse shapes using a BioRID test dummy and 8 measures to assess whiplash potential based on previous best practice. Given the complexity of the test and with more experience, a real-world evaluation of the current protocol was undertaken. Three analyses were undertaken comprising an analysis of test outcome data, a logistic regression analysis, a ROC analysis, and a correlation analysis comparing crash and injury outcome. 13,389 drivers reporting whiplash injury symptoms to Folksam Insurance in Sweden were studied, of which 1,266 occurred in cars tested by Euro NCAP. For all occupants reporting initial symptoms, the risk of permanent medical impairment was followed up according to the procedure used by Swedish insurance companies. Test scores according to Euro NCAP, JNCAP and IIWPG protocols were calculated, as well as combinations of the three Euro NCAP pulses. For each combination or protocol, the test score was compared with the real-world outcome. A correlation analysis of the included injury criteria was also performed for the three crash pulses included.

The results showed that overall Euro NCAP, JNCAP and IIWPG all predict real-world whiplash injury outcome in terms of Permanent Medical Impairment (PMI). Based on limited data available, there was no statistical evidence using logistic regression and ROC analyses that any of the three tests performed better than any other. Correlations between the test scenarios of each of the three protocols, as well as the outcome associations with crash outcomes, suggested consistent improvements in the risk of permanent medical impairment. The main strength of the analyses conducted here was to show the validity of Euro NCAP, JNCAP and IIWPG whiplash test protocols when measured against real-world crash outcomes, which are the most important criteria showing that the tests are appropriately designed to help prevent injuries among the community. Some caution needs to be taken with these findings as many were not statistically significant because of the limited number of cases available. Further evaluation when additional data are available is warranted.

PAPERNO.15-0277-O

Euro NCAP's First Step to Assess Autonomous Emergency Braking (AEB) for Vulnerable Road Users

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ABSTRACT

Following the implementation of AEB City and AEB Inter-Urban systems in Euro NCAP's safety rating in 2014, a third type of AEB technology, Autonomous Emergency Braking for Vulnerable Road Users (AEB VRU), will be added to the overall assessment of new vehicles in 2016. The introduction of AEB VRU will be done in two phases where in 2016 AEB Pedestrian is implemented followed by AEB Cyclists in 2018.

AEB VRU will be awarded as part of the assessment of Pedestrian Protection and represents the next step to improve the protection of vulnerable road users, complimentary to the existing subsystem tests to the vehicle front end. Following system tests in common pedestrian accident scenarios, more challenging and demanding cyclist scenarios are planned in a subsequent phase.

In close corporation with the car industry represented by the ACEA, JAMA and KAMA associations, Euro NCAP has developed detailed test and assessment procedures for AEB Pedestrian. The procedures are based on the existing car to car AEB test and assessment protocols and validated and checked for repeatability and reproducibility at several Euro NCAP laboratories. This paper describes both the test and assessment protocols.

PAPERNO.15-0292-O

Evaluation of Motorcycle Helmet Usability and Stability in the Consumer Safety Rating Program CRASH

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ABSTRACT

A review of certain aspects of the Consumer Rating and Assessment of Safety of Helmets (CRASH) for motorcyclists was undertaken. The paper examines the relationships between the assessment of helmet stability with volunteers and other usability assessments. The paper reports on how these assessments are incorporated into the Consumer Rating and Assessment of Safety Helmets (CRASH) and general relationships between Safety Scores and Ergonomic Scores. Ninety (90) motorcycle helmets were evaluated in the years 2011 to 2014 involving dynamic stability tests, dynamic strength of retention tests and usability tests with six participants. All helmets complied with AS/NZS 1698: 2006. The participants rated each helmet across ten items using a five point Likert scale. Forward, rearward and lateral pull tests were performed on each participant with each helmet. The force required to move the helmet with respect to the scalp was measured. The analysis revealed a number of important findings. First, safety performance tests are not correlated with ergonomic assessments of the helmets, including formal usability assessments. This observations highlights the importance of providing both safety and ergonomic information to motorcyclists. Helmet mass ranged between

approximately 1 kg and 2 kg in the sample assessed. On the assumption that the total Safety Score reflects a helmet that offers greater protection in a crash, a heavier helmet within the sample assessed offers more protection to the motorcyclist. Full face helmet types also performed better on total Safety Score than the open face helmet. Full face helmets were heavier than open face styled helmets. Differences in the total Ergonomic Score by helmet type were fewer than those observed with Safety Scores. There were strong correlations between the rater responses between pairs of questions regarding comfort, fit, but not restraint adjustment. Although there is some overlap between these questions, each question appears to elicit a slightly different response across all helmet types and raters. Helmet mass is either not correlated or weak to moderately correlated with user ratings. This suggests that the raters are considering other factors, not simply mass, when rating helmet weight. The raters might be considering the mass distribution, for example. In general, helmet stability as measured quasi-statically on each rater was weakly associated with the raters' assessment of the helmet. This suggests that the motorcyclist's impression of fit is not a strong indicator of helmet stability. Ease of use of operation was only weakly associated, based on these results, with the forces required to displace the helmet on the rater's head. Correlations between the stability test forces by direction (front, rear and lateral) were strong.

PAPERNO.15-0314-O

The Enhanced U.S. NCAP Five Years Later

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ABSTRACT

The U.S. New Car Assessment Program (NCAP) encourages vehicle manufacturers to make safety improvements to their vehicles through its award-winning consumer information-based 5-Star Safety Ratings Program. Occupant injury readings have decreased and star ratings have generally improved since the program was enhanced in the 2011 Model Year (MY). This paper summarizes vehicle crash test results for the five MYs since the program was last upgraded to demonstrate how quickly vehicles have been redesigned to achieve high ratings under the more stringent requirements. As a result, most vehicles are achieving 4- or 5-star ratings. Though there are still vehicles the agency has tested that do not achieve the highest ratings, the performance of the majority of vehicles tested under the enhanced program is excellent. This sets the stage for the agency to begin exploring the possibility of making additional changes to the current program to spur even further vehicle safety improvements through market forces and consumer demand. The NCAP's crash test data (specifically, occupant injury data) and star ratings derived from those data will be used throughout this study. Occupant performance from the first year of the enhanced program will be compared to more recent results. A comparative analysis of paired data for vehicles that have been tested and retested under the enhanced NCAP will also be shown. These analyses will serve to demonstrate the effectiveness of the program in encouraging vehicle manufacturers to make immediate design changes that improve the occupant protection afforded by their vehicles.

PAPERNO.15-0315-O

A Methodology to Derive Precision Requirements for Automatic Emergency Braking (AEB) Test Procedures

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ABSTRACT

AEB Systems are becoming important to increase traffic safety. Test procedures in testing for consumer information, manufacturer self-certification and technical regulations are used to ensure a certain minimum performance of these systems. Consequently, test robustness, test efficiency and finally test cost become increasingly important.

The key driver for testing effort and test costs is the required repeatable accuracy in a test design - the higher the accuracy, the higher effort and test costs. On the other hand, the performance of active safety systems depends on time discretization in the environment perception and other sub-systems: for instance, typical sensors supply information with a cycle time of 50 - 150 ms. Time discretization results in an inherent spread of system performance, even if the test conditions are perfectly equal.
The proposed paper shows a methodology to derive requirements for a test setup (e.g. test repeats, use of driving robots, ...) as function of AEB system generation and rating method (e.g. Euro NCAP points awarded, pass/fail, ...). While the methodology itself is applicable to AEB pedestrian and AEB Car-Car scenarios, due to the lack of sufficient test data for AEB Car-Car, the focus of this paper is on AEB pedestrian scenarios.
A simulation model for the performance of AEB Pedestrian systems allows for the systematic variation of the discretization time as well as test condition accuracy. This model is calibrated with test results of 4 production vehicles for AEB Pedestrian, all fully tested by BASt according to current Euro NCAP test protocols.
Selected parameters to observe the accuracy of the test setup in case of pedestrian AEB is the calculated impact position of pedestrian on the vehicle front (as if no braking would have occurred), and the test vehicle speed accuracy. These variable was shown in real tests to be repeatable in the range of ± 5 cm and ± 0,25 km/h, respectively, with a fully robotized state of the art test setup.
The sensitivity of AEB performance (measured in achieved speed reduction as well as overall rating result according to current Euro NCAP rating methods) towards discretization and the sensitivity of performance towards test accuracy then is compared to identify economic yet robust test concepts.
These comparisons show that the available repeatability accuracy of current test setups is more than sufficient for today's AEB system capabilities. Time discretization problems dominate the performance spread especially in test scenarios with a limited pedestrian dummy reveal time (e.g. child behind obstruction, running adult scenarios with low car speeds). This would allow to increase test tolerances to decrease test cost.
A methodology which allows to derive the required tolerances in active safety tests might be valuable especially for NCAPs of emerging countries that do not have the necessary equipment (e.g. driving robots, positioning units) available for the full-scale and high tolerance EuroNCAP active safety procedures yet still want to rate active safety systems, thus improving the global safety.

PAPERNO.15-0376-O

The Australian Child Restraint Evaluation Program: An Update on Dynamic Assessment Protocols and Observed Dynamic Performance of Child Restraint Systems

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ABSTRACT
The purpose of the Australian Child Restraint Evaluation Program (CREP) is to provide consumers with independent safety information; and to apply commercial and public consumer pressure on manufacturers to deliver child restraint systems (CRS) that perform well beyond the requirements of the Australian Standard. This paper describes the

evolution of the dynamic assessment protocols and presents a summary of areas where improvement in dynamic performance has occurred. Areas of dynamic performance where there is still room for improvement, is also reviewed.

The dynamic assessment protocol has evolved from a system that separately scored the performance of CRS in frontal, 90 degrees and 66 degrees simulated impacts to a system that provides a single overall score for front and side impact tests to determine CRS ratings. The current protocols also nominate a number of 'Critical' 'Performance Aspect' (PAs) and a CRS is limited to one star if a score of '0' is achieved for any critical PA. There have also been significant changes to the dynamic test and assessment methods over the years to ensure assessment methods are as objective as possible, and some variation in the types of performance features assessed. For rearward facing infant restraints, CREP currently assesses the ability of the CRS to retain the head and torso in front and side impacts, control upward and rotational displacement of the CRS in rebound and distribute the load over the back of the dummy, in frontal testing, , manage dummy head and torso energy in frontal testing and manage dummy head energy in side impact. Similar assessments of dummy and head retention and energy management are used in the rating of forward facing child restraints. These assessments also include head and knee excursion. For booster seats, it includes the ability of the booster to provide and maintain good sash belt geometry, and to prevent submarining in frontal impacts. Assessments of head retention and energy management in side impact and dummy retention both in near and off-side impacts are also included for booster seats. There have been substantial improvements in the side impact protection features of rearward facing and forward facing child restraints observed in the program, and increasingly better performance of booster seats in maintaining good seat belt geometry in frontal impact. However, there is a need for more attention to head energy management in side impact, particularly among rearward facing restraints. Among rearward facing restraints, there are also concerns about poor performance of most restraints to adequately distribute crash forces through the back of the torso in frontal impact. Among forward facing restraints, there are concerns over head containment during rebound in frontal impact.

While there have been significant improvements to the test and assessment methods used in CREP there is a possibility that some aspects of good performance are being overstated and aspects of poor performance understated due to limitations in the assessment and rating procedures. Areas for possible future refinements of the protocols are also discussed.

Technologies and Policies of Driver Monitoring

Thursday, June 11, 2015 | 8:30 a.m.- 12:30 p.m.
Chairperson: Trent Victor, Sweden| Co-Chair: Dominique Cesari, France|
TRACK A | Room: F3

PAPERNO.15-0276-O

Driver Alcohol Detection System for Safety (DADSS) – A Non-Regulatory Approach in the Development and Deployment of Vehicle Safety Technology to Reduce Alcohol-Impaired Driving – A Status Update

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ABSTRACT
The National Highway Traffic Safety Administration (NHTSA) and the Automotive Coalition for Traffic Safety (ACTS) began research in February 2008 to try to find potential in-vehicle approaches to the problem of alcohol-impaired driving. Members of ACTS comprise motor vehicle manufacturers representing approximately 99 percent of light vehicle sales in the U.S. This cooperative research partnership, known as the Driver Alcohol Detection System for Safety (DADSS) Program, is exploring the feasibility, the potential benefits of, and the public policy challenges associated with a more widespread use of non-invasive technology to prevent alcohol-impaired driving. The 2008 cooperative agreement between NHTSA and ACTS for Phases I and II outlined a program of research to assess the state of detection technologies that are capable of measuring blood alcohol concentration (BAC) or Breath Alcohol Concentration (BrAC) and to support the creation and testing of prototypes and subsequent hardware that could be installed in vehicles. This paper will outline the technological approaches and program status.

PAPERNO.15-0380-O

Introduction of a Solid State, Non-Invasive, Human Touch Based Blood Alcohol Sensor

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ABSTRACT
This paper presents an overview of the theory and implementation of a touch-based optical sensor (TruTouch sensor) for monitoring the alcohol concentration in the driver of a vehicle. This novel sensor is intended to improve driver safety by providing a non-intrusive means of notifying a driver when their blood alcohol concentration may be too high to operate a vehicle safely. The optical alcohol detection system has successfully completed several stages of development and validation. A commercially available, industrial version of the system (TruTouch 2500, or Mark 1) has undergone extensive clinical testing and field validation. Under the DADSS (Driver Alcohol Detection System for Safety) Program, a compact semiconductor version (Mark 2) of the optical system has been developed targeting use in consumer vehicles.

Based on proven semiconductor laser technologies, the Mark 2 sensor system has demonstrated excellent spectral accuracy and precision and is currently undergoing laboratory validation testing. A demonstration vehicle version of the system has been designed and will be implemented following completion of the laboratory validation testing.

PAPERNO.15-0410-O

The Relationship between BAC and BRAC of Healthy Korean Males

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ABSTRACT

BrACs (Breath alcohol concentrations) are often converted to the corresponding BACs (blood alcohol concentrations) by multiplying a partition ratio, Q. However, according to the previous researches, it has been revealed that it depended upon the nations. So, the partition ratio (or Q-factor) of healthy Korean adult males and its correlation to some variables including TBW (total body water), BMI (body mass index), BFM (body fat mass), and PBF (percentage of body fat) were revealed. The average of partition ratio did show particular difference around 100 when the subjects were divided with two sets: below and above the average of TBW. The partition ratio of Korean healthy males showed 1,913 (95 % confidence interval (CI) from 1,889 to 1,937) for whole time intervals. However, when Q was averaged after peak BACs, it gave 2,011 (95 % CI range from 1,982 to 2,040). Bland-Altman plots revealed the compatibility of measurement method of multi-gas analyzer, and the biases according to the partition ratios (Q=2,100 and Q=1,913) gave -0.0052 (95 % CI from -0.0059 to -0.0045) and -0.0004 (95 % CI from –0.0011 to +0.0003), respectively. From this study, the partition ratio of Korean healthy males has been reported for the first time with massive medical experiments.

PAPERNO.15-0458-O

Unobstrusive Breath Alcohol Sensing System

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ABSTRACT

Although the vast majority of vehicle drivers are sober, drunk driving remains to be a major contributor to fatal accidents. Massive deployment of unobtrusive breath alcohol sensing systems could potentially save tens of thousands of lives worldwide every year by preventing drunk driving [1]. The work reported here is ultimately aiming at such a system. The technical performance of the present sensing system with respect to automotive requirements is summarized, and new results towards unobtrusive breath alcohol determination within vehicle compartments are presented.

Breath alcohol concentration (BrAC) can be determined unobtrusively if (i) the sensing system provides real-time signals with adequate accuracy corresponding to the local concentrations of both alcohol and a tracer gas, e g CO2, (ii) the dilution of the breath is not excessive in relation to background concentrations, (iii) the sensor location can be seamlessly integrated into the interior of a vehicle cabin. All three of these aspects are addressed in the present paper.

More than a hundred prototypes based on infrared spectroscopy were fabricated and subjected to automotive qualification tests in the full temperature range -40 … +85^{0}C. In the majority of tests, adequate performance was noted. Measures are now being taken to fill remaining performance gaps. Test results with human subjects were positive and in accordance with expectations with respect to physiological variations. In-vehicle tests showed that for the best sensor position, passive breath samples allowed BrAC to be determined at a resolution of 2-4% of the US legal limit, providing proof-of-principle for unobtrusive testing. Nevertheless, vehicle integration remains to be the major technological challenge to the objective of deployment on a large scale of unobtrusive driver breath alcohol determination.
The feasibility of unobtrusive breath alcohol determination in vehicles, and adequate performance of a sensor system based on infrared spectroscopy have been experimentally demonstrated. The alcohol sensing system may advantageously be integrated into vehicles, and may also be combined with other technologies to monitor driver impairment.

PAPERNO.15-0453-O

Mitigating Drowsiness: Linking Detection to Mitigation

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ABSTRACT
Drowsy driving contributes towards up to 24% of crashes and near crashes observed; 886 fatal crashes per year can be attributed to drowsy, fatigued or sleeping drivers. Drowsiness mitigation technology is composed of a detection algorithm and a mitigation component. This paper is primarily concerned with the latter, specifically for a driving simulation study about mitigating drowsy driving. The study is part of NHTSA's Driver Monitoring of Inattention and Impairment using Vehicle Equipment (DrIIVE) program. The detection algorithm incorporates time series probabilistic estimation using a Hidden Markov Model, so a drowsiness prediction at any time is dependent on a previous history of observations. Two mitigation methods are designed for testing in the simulation study. One is a three stage audio/visual alert that requires a driver response through a button press. The second is a binary haptic alert that uses a vibrating seat. Additionally, each mitigation will include three varying levels of sensitivity: a nominal model, an over-sensitive model, and an under-sensitive model. These variations will expose drivers to different numbers of false alarms while also potentially missing episodes of drowsiness. Various parameters in the detection algorithm were tested and the vote thresholds of two Random Forest models were selected for variation. It was observed how these parameters affected the output of the detection and mitigation system using previously collected drowsy driving data. Three specific levels were chosen as candidates for the experiment. It is hoped that the study will answer questions about how effective a mitigation system is at changing driving performance, whether drivers willfully ignore the mitigation, and how many alerts are too many.

PAPERNO.15-0226-O

Analysis of the Robustness of Steering Pattern Based Drowsiness Detection

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ABSTRACT
Several studies show that up to one in four severe traffic accidents can be attributed to drowsiness. Drivers often over-estimate their fitness level or are not aware of the danger that always accompanies drowsy driving.
Since associations like the NHTSA pointed to the relevance of this topic, more and more research has been conducted and in the meantime there is also a variety of commercial systems on the market to address this risk.

In this paper, we do not aim to find new methods of detecting drowsiness of a driver. Our approach is rather to choose an established method and enhance it in a way that it not only performs well in a driving simulator but also in real world drives.
The chosen drowsiness detection method is the observation of the steering wheel angle signal. It has been shown that the frequency of occurrence of a typical steering pattern, which can roughly be described as a deadband followed by a rather fast correction, is an indicator for the state of drowsiness of a driver. The advantage over other techniques like camera-based detection is that it can run in standard equipped cars. Thus it is available for the largest number of drivers and can thereby achieve the greatest effect on accident avoidance.
We investigate the chosen detection method in real world drives and discuss which other effects not related to drowsiness can evoke the described steering pattern. We focus on environmental effects like crosswind and can show that those events may lead to an increase of the amount of steering patterns. Finally, we quantify the influence on drowsiness measures. The underlying database comprises more than two million kilometers of more than one thousand drivers, all real-world drives.
Our evaluation shows that particularly on routes or in situations where those environmental influences accumulate, the drowsiness measure can be affected to an extent that leads to false triggering of the system. Therefore, we suggest measures that can be taken to reduce the influence of steering patterns that are not related to the driver's drowsiness state.
The aim of most drowsiness detection systems is to inform a driver when his state has reached a critical level and to motivate him to take appropriate measures. This presupposes confidence in the system. False warnings will negatively affect the credibility of the system.
Our purpose is to show the importance of enabling this kind of system to recognize external influences, thus making detection more robust. We consider it very important to make such systems as reliable and credible as possible, as otherwise the driver will not take the advice the system will give him. Limiting the influence of external factors is a key to achieving this goal.

PAPERNO.15-0377-O

The Potential for Adaptive Safety through In-Vehicle Biomedical and Biometric Monitoring

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ABSTRACT

A 2009 study by the National Highway Traffic Safety Administration identified certain medical conditions as contributing factors in crash causation (Hanna 2009). It was found that about 1.3% of all crashes included in the National Motor Vehicle Crash Causation Survey (NMVCCS) were precipitated by driver reported medical emergencies and 84% of the drivers in crashes precipitated by medical emergencies experienced seizures (epileptic and others), blackouts (non-diabetic), and diabetic reaction prior to the crashes. Drivers who had crashes precipitated by medical emergencies were more likely to sustain severe injury (28% for incapacitating injury and death for crashes with medical emergency; 11% for crashes without medical emergency). Thus, the premise exists that there may be benefit to identify the driver (and other occupants) of the vehicle as well as monitor their current health status through passive or active methods. This monitoring could take into account chronic conditions (such as bone mineral density) through driver input or through initial vehicle startup measurements which could be used to provide optimal comfort or safety system performance. Additional information about the driver's health or behavioral conditions could be interpreted from blood pressure, heart and respiration rate, blood glucose levels and other physiological parameters and could lead to vehicle intervention in driving and/or alert EMS or police of the impending health condition that may affect driving or cause a crash. This monitoring could be done in many ways such as the recent rapid growth in wearable technology with the ability to pair to apps.

This paper will discuss issues related to driver behavioral and health monitoring and review potential technologies for monitoring and as well as methods for biometric identification. Recent publications on driver crash risk due to chronic and acute health conditions will be summarized. Finally, applications that may be associated with the monitoring will be discussed.

PAPER NO. 15-0150-O

Application of Biologically Inspired Visual Information Processing in Affective Driver Status Monitoring

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ABSTRACT

Recent times have seen an increased interest in technologies of driver assistance. Understanding the driver¡¯s current status is crucial for the implementation of Advanced Driver Assistance System (ADAS) and Driver Status Monitoring (DSM). Emotional factors such as anger have been long attributed to aggressive driving behaviours and increased likelihood of road accidents. Therefore, being able to accurately detect the affective states of the vehicle occupant will be critical for enhanced safety and comfort.

In this paper, we present a methodology for the evaluation of the emotional states of vehicle drivers. The proposed approach performs an assessment of the emotional states by using combination of biologically inspired visual information processing and neural networks coupled with feedback mechanisms. The system consists of the following stages: (1) biologically inspired image pre-processing; (2) facial feature extraction; (3) multilayer perceptron for classification; and (4) feedback mechanism. The system has been preliminary validated by using data available from Japanese Female Facial Expression (JAFFE) database. Four affective states were identified and tested, which includes anger, sadness, and happiness. Subsequent tests have shown the successful detection rate of 91.3% with test images, and over 70% correct classification in images with Gaussian noises, respectively.

Continuation of
Crash Avoidance #1: Safety Performance and Effectiveness of Driver Assistance Technologies, Test & Evaluation Procedures, Benefits Assessment

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Thursday, June 11, 2015 | 10:30 a.m.- 12:30 p.m.
Chairperson: Clarie Rees, United Kingdom|
Co-Chair: Bernie Fronst, United Kingdom|
TRACK A | Room: F3

PAPERNO.15-0437-O

Development of a Standardized Method for Making Characteristic RADAR Measurements of Example Vehicles and Surrogate Targets

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ABSTRACT
Testing of Advanced Driver Assistance Systems (ADAS) often requires the use of a surrogate vehicle to represent a real vehicle in conflict scenarios. Use of a surrogate vehicle is required if there is a potential for a collision during testing. In order to ensure that the test results are representative of what will occur on the road, the surrogate vehicle should appear to the test vehicle as a real car.

This paper describes a method and equipment developed for measuring and analyzing the radar signature of typical vehicles and surrogate targets. The method was then applied to eight small passenger cars to better understand what the radar signature of representative passenger vehicles are.

A special-purpose trolley was designed to serve as a portable, self-contained measurement, data acquisition and power platform. It consists of a wheeled trolley base and a vertical structure to which the various equipments are attached. The sensor trolley has 3 retractable feet that are used to make it a stationary device during measurements. The front two feet can be used for fine roll adjustment and the rear foot can be used for fine pitch adjustment. Mounted to the trolley are a commercial production 6-77 GHz RADAR sensor, a sensor bracket with roll angle level and scope sight, a data acquisition system, a laptop computer, a 12 volt battery and a power distribution box.

Eight small passenger cars were measured, three sedans, three hatchbacks, and two microcars. Small passenger cars may represent a worst case in terms of vehicle visibility. The representative vehicle radar measurements were made taken from five viewing angles and at three distances for each angle. The data from these measurements are presented.

PAPERNO.15-0015-O

Unmanned Target Vehicle for Active Safety Evaluation in Cut-In Test Scenarios

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ABSTRACT
In recent years, active safety systems are introduced to the markets and many of them are adopted to improve the possibility to avoid the accidents. These active safety systems include AEBS (Automatic Emergency Braking System,) LKAS (Lane Keeping Assistant System,) BSD (Blind Spot Detection,) and so on. The evaluation methods for those systems also have been developed and determined as international standards. Additionally, target systems for evaluation have been

developed too. However, they are usually designed for testing straight rear collision scenarios. To reproduce other scenarios such as cut-in situations, a new concept of the target system is needed. So, in this work, the unmanned target vehicle are designed and developed.
The target vehicle is developed as an unmanned vehicle for accurate path following performance. A DGPS with 2cm accuracy and heading angle IMU are installed for the path following function. A soft dummy which resembles a typical SUV is attached on the unmanned target vehicle. To reproduce accident scenarios safely, the target vehicle should be designed to protect the hunter vehicle and the target vehicle itself from the crash shock of the collision situation. The target vehicle in this work is developed with a shock absorber system in the rear part of the target vehicle.
The rear part of the target vehicle is designed to have similar characteristics with a real vehicle in visual shape for vision systems and radio frequency reflection for radar systems. The shape and the material of the part is selected for the hunter vehicle to recognize the target vehicle as a real SUV.
The structural and dynamic analysis are carried out for the target performance. Also, evaluation experiments of the cut-in scenarios are carried out to test the hunter vehicle with the AEBS.
The dynamic performance results of the target vehicle will be presented. The results include the limit of impact speed, maximum speed, maximum lateral speed and accuracy of path following logic. The AEBS performance results of the hunter vehicle will be presented in the test cut-in situation.
In this work, test scenarios to evaluate the hunter vehicles are carried out especially for the 'Rear collision and Cut-in' situations. Frontal collision and accidents in intersection situation are excluded. The hunter vehicles with AEBS are only tested for the evaluation experiments. The test speed is set less than 40km/h.

PAPERNO.15-0037-O

Prospective Estimation of the Effectiveness of Driver Assistance Systems in Property Damage Accidents

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ABSTRACT

Projects for the analysis of traffic accidents are focused mostly on personal damage. But analyses show that property damage occurs 42 times more often than personal damage [4]. Officially registered accidents on German roads result in mere damage to property (2.1 mio accidents [1]). A significantly higher number of property damage accidents are not reported to the police. Some of which are reported to the insurers [2]. A significant number of minor damage does not appear in the statistics. According to [3] the number of minor damage cases amounts to 4.8 mio cases per annum. 35% of full comprehensive cover accidents occur at low speeds and pose a high potential for future advanced driver assistance systems (ADAS) [4]. Details of accidents involving minor damage cannot be found in official statistics. In “In-Depth” property damage analysis, the conflict leading to damage is of high relevance. Uncertainties need to be settled by means of an expansion of the existing accident conflict situations [4]. Currently, equipment rates of ADAS are low requiring a purchase incentive for customers. Based on [5] this paper describes how damages of vehicles can be classified and brought into relationship with ADAS functions and the vehicle itself. Various configurations and different materials of outer attaching parts (OAP), e.g. aluminum, CFRP or plastics induce variable costs of repair. For a prospective evaluation method of the monetary effect of ADAS it is necessary to know all influence parameters and to quantify them. The evaluation of vehicle concepts in combination with an ADAS is possible.
Keywords: In-Depth Property Damage Analysis, Field Effectiveness, Prospective Evaluation, Property Damage Risk Function, Accident Research.

PAPERNO.15-0220-O

Autonomous Emergency Braking for Cornering Motorcycle

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ABSTRACT

Research question

Autonomous emergency braking (AEB) has been indicated as a potential safety application not just for passenger cars and heavy goods vehicles, but also for motorcycles and powered two-wheelers (PTWs) at large. Motorcycle AEB (MAEB) was designed to produce autonomous deceleration of a host PTW in case of inevitable collision. Previous studies limited MAEB to the case of a PTW travelling along a straight, as the activation of AEB was considered hazardous for a leaning vehicle. This study aims to extend the applicability of MAEB to cornering scenarios.

Methods

A virtual PTW in a simulated environment was equipped with MAEB and Active Braking Control (ABC). MAEB consisted of a virtual obstacle detection device, triggering algorithms that identify inevitable collision states, and an automatic braking device. When an inevitable collision is detected for the host PTW and at the same time the rider is applying some braking force, MAEB deploys enhanced braking, which assists the rider reaching the maximum feasible deceleration. ABC consisted of control algorithms for the automatic braking device that stabilise the vehicle along the curved path. The complete system named MAEB+ was tested using detailed computer simulation reproducing real world crashes.

Data sources

The crash cases used for the simulations were selected from the in-depth crash dataset “InSAFE”, which collects severe road crashes in the metropolitan area of Florence. The selection criteria were the following: a) the PTW crashed into another vehicle; b) the PTW was travelling along a curved path with roll angle above 15 deg; c) the rider applied some braking force prior to impact; d) PTW loss of control was not the main contributing factor.

Results

In the simulation, MAEB+ was able to assist the rider in reducing the motorcycle speed prior to impact with higher deceleration compared to baseline MAEB and in maintaining the stability of the motorcycle.

Limitations

The potential benefits of the proposed system, expressed in terms of impact speed reduction or avoidance of fall events, cannot be directly correlated with actual benefits for the rider in terms of injury mitigation. In fact, risk curves expressing the level of injury for the rider as a function of kinematic quantities (such as impact speed) are not currently available for riders.

Significance of results

Previous studies showed that MAEB would typically apply to situations where the motorcycle is travelling along a straight path. However, this paper shows that MAEB associated to ABC can apply also to those cases where the PTW is leaning, thus contributing to prove and extend the robustness of MAEB.

PAPERNO.15-0058-O

AEB Real World Validation Using UK Motor Insurance Claims Data

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ABSTRACT

City Safety is a low-speed autonomous emergency braking (AEB) technology, first made available as standard by Volvo on their XC60 model series, and released in the UK in 2008. This technology has since been made available on a growing number of models, including the high volume seller Volkswagen Golf 7. This paper presents an analysis of the impact of AEB in the UK on claim losses using real world Insurer claims data. Statistical regression was used to compare the claims losses for the XC60 to that of a SUV control cohort of vehicles without any such system, and quantify any AEB effects identified. The influences of calendar year and vehicle age on claim risk were accounted for in the analysis. Estimated claim frequencies for the XC60 were lower than those of the control cohort, in all liability types: 8% lower for Third Party Damage, 6% lower for Own Damage, and 21% lower for Third Party Injury. More recently this approach has been employed to compare claim frequencies for the Golf 7 with the Front Assist AEB system with that of a Small Family car control cohort of vehicles, with similar qualitative results observed from an analysis of the initial data available. Furthermore a study of claim damage severity based around claim costs and repair times estimated lower severity levels for the XC60 relative to control cohorts, for own damage liability, of the order of 10%-15%. This study is the first of its kind using UK claims and indicates the potential benefit of AEB technology. Further statistical analysis is intended with additional risk information for the XC60 and Golf 7, and other AEB study vehicles.

PAPERNO.15-0121-O

Real-World Performance of City Safety Based on Swedish Insurance Data

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ABSTRACT

The number of passenger cars equipped with Auto Brake functionalities in traffic is increasing rapidly. Following this, the opportunity to study real world performance of these systems is growing. The low-speed Auto Brake system City Safety, launched in 2008 and a standard feature on all recent Volvo Cars' models, is a technology designed to help the driver mitigate and in certain situations avoid rear-end collisions at low speed by automatically braking the vehicle. Previous analysis of the City Safety technology showed promising results in terms of reducing real world crashes.

In this study, further evaluation of City Safety was performed based on insurance claims data. Using a unique dataset containing all new Volvo cars in traffic in Sweden from 2010 to 2014, including the possibility to control for other advanced driver assistance systems such as ACC, FCW and Auto Brake functionalities, the rate of rear-end frontal collisions per insured vehicle years was studied. First, car models with and without City Safety were compared. Second, the same car model with and without City Safety was compared, thereby controlling for specific characteristics in different models. Finally, the second generation of City Safety, that operates at speeds up to 50 km/h, was compared to the first generation (<30 km/h). Results showed that the overall claim frequency of rear-end frontal collisions was 28% lower for City Safety equipped models than for other Volvo models without the system. The result of the comparison between the same models was similar while no significant collision avoidance effect of the upgraded system to speeds up to 50 km/h was found. The expected crash mitigating effect of City Safety can be added to these results, providing a further potential to be explored in future real world follow-up studies.

This study confirms previous encouraging results of the crash reducing effect of the City Safety functionality. The findings of Auto Brake safety performance in real world traffic, shows the relevance of this type of vehicle systems for increased traffic safety and emphasizes the importance of the introduction of such systems on the market.

PAPERNO.15-0159-O

The Development of a Test Procedure Suitable for Use in Consumer Information Programmes to Assess the Performance of AEB Systems in Collisions Involving Vulnerable Road Users

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Thatcham, United Kingdom

ABSTRACT

In Europe, nearly 20% of all road deaths are pedestrians (Pace et al, 2012). Pedestrians have been protected only by the requirements for passive protection at the front of passenger cars and there has been little evidence to show that this measure has been effective. Autonomous Emergency Braking (AEB) systems have been clearly demonstrated to substantially reduce the incidence of car-to-car rear crashes and manufacturers have now extended the functionality to pedestrian, and in some cases pedal cyclist, collisions. If a comparable level of effectiveness is proven, then these systems will offer substantial reductions in the number of those killed and seriously injured on our roads. The research challenge described by this paper was the development of a test procedure that could be used to encourage the fitment of these systems and the development of high levels of performance in a way that could be linked to real world safety.

Thatcham Research led the AEB Group (a partnership of insurance research centres, OEMs and Tier ones) in the development of test procedures. This contributed substantially to the Harmonisation Platforms in a major collaboration with the vFSS group and the EU funded ASPECCS project. Work began with studies of real-world accident data. A cluster analysis identified the most prevalent collision scenarios and smaller samples of more detailed data were used to characterise each scenario in terms of speeds, impact points, relative positions and sight lines. Physical testing identified the characteristics required of the pedestrian test target and the performance of production and advanced prototype vehicles as well as establishing the conditions required for repeatability and reproducibility.

In Europe almost 75% of serious pedestrian crashes can be characterised by three scenarios: walking from the nearside of the road with open sight lines; running from the far side of the road; and walking out from behind a parked vehicle. In the vast majority of crashes the vehicle involved was travelling at 60 km/h or less. To ensure the systems worked well in the real world it was found that the test should involve adults and children, different impact points and different pedestrian speeds. The pedestrian target found to be most effective was the 4A design, and this was further tuned to optimise the radar and visual signatures to ensure consistent function across different sensor types and proving ground locations.

AEB has considerable potential to reduce the frequency and severity of vulnerable road user collisions. Robust test procedures, representative of real world collisions, have been developed and adopted by Euro NCAP for implementation in the 2016 ratings. However, VRU collisions are a problem in many areas of the world and the harmonisation of these tests and assessments in other NCAP regimes remains a priority, alongside the continuous technical development to expand the tests to include night-time performance and functionality in pedal cycle collisions.

Integrated Safety from Pre-Crash to Crash to Post-Crash

Thursday, June 11, 2015 | 8:30 a.m.- 12:30 p.m.
Chairperson: Stephen Ridella, United States|
Co-Chair: Jac Wismans, The Netherlands|
TRACK B | Room: F4

PAPERNO.15-0060-O

New Integrated Assistance Functions for Real World Accident Scenarios

CHRISTOPH HARTMANN, SAKHEEN HARLAPUR
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Continental AG - Division Chassis & Safety, Germany
THOMAS BRANDMEIER
Technische Hochschule Ingolstadt, Germany

ABSTRACT
Investigation of several accident databases consistently identified guardrail and embankment accidents as highly relevant in the context of real world accident scenarios that are not in the focus of today's vehicle safety functions. This work demonstrates the potential of future vehicle safety functions to reduce the severity of such accidents. To achieve this, two vehicle lateral controllers are in development that assists the driver in guardrail and embankment accident situations. A Linear Quadratic Regulator (LQR) approach, based on a single track model, is used to stabilize the vehicle in these situations with the goal to reduce the risk of secondary collisions and a rollover of the vehicle. Simulation results demonstrate the potential of the vehicle lateral controllers to stabilize the vehicle after a guardrail collision and to keep it in a safe area next to the guardrail. It is also demonstrated that the risk of a rollover in an embankment due to erroneous driver steering can be reduced. Further research is required to investigate the influence of driver inputs to the controllers in the mentioned accident situations. It needs to be discussed how the new controllers could be incorporated in the existing and future vehicle safety architecture.

PAPERNO.15-0335-O

The AEB System with Active and Passive Safety Integration for Reducing Occupants' Injuries in High-Velocity Region

EUNG-SEO KIM, SUK-KI MIN, DONG-HYUN SUNG, SANG-MIN LEE, CHANG-BONG HONG
Hyundai Motor Company, Korea, Republic of

ABSTRACT
AEB (Autonomous Emergency Braking) is a representative safety system that assists a driver to avoid forward collision or mitigate crash velocity resulting in reduction of occupant¡¯s injury risk using ADAS sensor. This paper focuses on establishing appropriate PSB activation time in order to minimize occupant forward movement and head & neck injuries in the event of collision when it is unavoidable in the aspect of active and passive safety system integration. And also, it is the other goal that decreases the collision velocity by applying more efficient pre-braking profile. For this, AEB test is performed with H-3 5% & 50% human dummy seated in the passenger side. The test vehicle is equipped with Lidar and camera sensor fusion AEB system, PSB (Pre-Safety seatBelt) and a premium ESC module. From this study, the last time to

activate PSB considering occupant¡¯s injury and the improved pre-brake profile beneficial to collision velocity reduction and occupant¡¯s behavior were verified.

PAPERNO.15-0374-O

Evaluation of Occupant Protection Systems: From a Preventive to a Pre-Impacting Restraint System

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Daimler AG, Germany
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Daimler AG, Mercedes-Benz Cars Development, Germany

ABSTRACT

The safety of modern vehicles has reached such a high standard that experts view the remaining potential for improvement of conventional restraint systems as nothing more than minimal. However the use of information gathered during the pre-crash phase added to the combination of preventive and conventional restraint systems can reveal additional potential.

One example of this is the reversible pretensioner of the PRE-SAFE® system, launched in 2002, which can hold occupants in their position shortly before a potential collision and thus reduce forward displacement to offer improved protection in an accident.

This approach was further developed with the introduction of PRE-SAFE® Impulse, which debuts in the current S-Class of MJ 2013. PRE-SAFE® Impulse systems rapidly accelerate occupants at an early phase of the crash by moving them in the direction of the impact force so that the difference in kinetic energy between the vehicle and occupants can start to be reduced as early as possible. As a consequence the total energy does not have to be dissipated entirely during the crash itself, but is distributed over a minor initial impact and a major impact whose intensity is reduced accordingly.

The new PRE-SAFE® Impulse Side System, a pre-impacting restraint system, does not only applies this idea for side crash but brings the concept one step further. Previous measures for improving side impact protection were primarily implemented on the vehicle itself and did not directly influence the occupants prior to the crash. With PRE-SAFE® Impulse Side, a defined energy, is transferred to the occupant, who is set in motion already before the collision occurs. Therefore PRE-SAFE® Impulse Side is the very first of a new generation of pre-impacting restraint system whose field of action will be extended prior to the collision due to the integration of active and passive safety.

To this end, the PRE-SAFE® Impulse Side system uses a 360-degree sensor system, which permanently senses the car surroundings, to anticipate an unavoidable collision.

Using numerical simulation as well as sled and vehicle testing, relevant occupant loads have been shown to be reduced by 30 percent on average with the use of PRE-SAFE® Impulse Side.

PAPERNO.15-0424-O

Run Off Road Safety

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ABSTRACT

Run off road events are frequent and can result in severe consequences. The reasons for leaving the road are numerous and the sequence the car is subjected to differs in most events. The aim of this study is to holistically address safety improvement in run off road events, presenting methods for evaluation as well as examples of countermeasures for the whole sequence from normal driving to post-crash.

Real world data, comprising statistical and in-depth crash data as well as driving data from Volvo Cars' database in Sweden, forms the basis for understanding of influencing factors and mechanisms related to occurrence of the event as well as occupant injury. Countermeasures are presented along with the test methods which were developed based on the mechanisms identified. The test methods include road off road avoidance test methods, complete vehicle crash tests, and rig tests; such as occupant positioning using a robot rig and vertical loading tests using a drop tower rig.

Countermeasures addressing run off road safety are developed and verified using the identified test methods and integrated into vehicle design. Examples of systems addressing road departure avoidance aspects are Driver Alert Control and Lane Keeping Aid. Countermeasures specifically addressing occupant protection are occupant positioning by detecting run off road events and activating an electrical reversible safety belt pretensioner, as well as unique energy-absorbing functionality in the seat. Post-crash measures are enhanced by added activation of eCall in some run off road scenarios.

Optimally, avoiding the run off road is most beneficial and this study provides some initial steps illustrated by production systems. However, if run off road occurs, one priority is to reduce vertical occupant loadings when landing on the wheels after a free-flight, a rollover or when going into a ditch and impacting an embankment. This type of loading could result in thoracic-lumbar spine fractures. The design of the unique energy absorbing functionality in the seat, put into production 2015, will help provide important enhanced occupant protection. Additionally, injury outcome is influenced by the occupant position during the event: head and arms flinging around impacting the interior, bent postures reducing the tolerances of spinal injuries, and sub-optimal occupant positioning relative to protection systems. The unique run off road detection and safety belt pretensioning early in the events, together with the seat backrest's side supports, will assist the occupant to stay positioned during the event and help improve protection.

This study is based on a holistic approach to safety, covering the whole event from normal driving to crash care, introducing world first production technology enhancing occupant protection in these diverse and complex events. It goes beyond standardized safety evaluation of today and it provides an illustrative example on how safety systems can take action across the entire crash sequence and the interaction of different types of systems adding to the effect of addressing real world protection needs.

PAPERNO.15-0409-O

Enhancement of Occupant Safety in Offset Frontal Vehicle Collision: Using Novel Mathematical Modelling Alongside Vehicle Dynamics Control Systems

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ABSTRACT

Occupant safety is one of the most important issues for vehicle manufacturing. Active safety plays an important role to protect the occupant during the crash events. In this paper, vehicle dynamics control systems (VDCS) are used to enhance the occupant safety in offset frontal vehicle collision. VDCS are activated to optimize the vehicle in impending collision. A new mathematical modelling of the vehicle alongside VDCS is developed to study the effect of vehicle dynamics control systems on vehicle collision mitigation. A multi -body occupant mathematical model is developed to capture the occupant kinematics during frontal offset collision. Different cases of vehicle dynamics control systems have been used to show their effect on the occupant dynamic response. The occupant deceleration and the occupant's chest and head rotational acceleration are used as injury criteria. It is shown from the numerical simulations that the occupant behaviour can be captured and analysed quickly and accurately. Furthermore, it is shown that the VDCS can affect the crash characteristics positively and the occupant safety is improved.

PAPERNO.15-0215-O

The Integrated Safety Concept of the Ultra-Compact Electric Vehicle Visio.M

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ABSTRACT

A great opportunity for increasing range and decreasing the production costs of battery-powered vehicles is to lower vehicle weight as far as possible. To this end, designers not only can incorporate lightweight materials, but also reduce the size of the vehicle and limit the equipment installed as excellent weight-saving strategies. Since this strategy could lead to crash incompatibility, ultra-compact electric cars are subjected to enormous loads in the event of a collision with a heavier vehicle. The high structural rigidity and limited deformation paths produce a high crash pulse, with higher forces acting on occupants than are experienced in conventional vehicles. The objective of the safety task force within the Visio.M project funded by the German government was to draft, implement, and test a concept that resolves these conflicting interests and provides sufficient protection for ultra-compact vehicles. Using an analysis of the potential accident scenario involving ultra-compact electric vehicles as a starting point, specific safety requirements were derived for these vehicles. To meet these requirements, a strategy for an integrated safety design was developed to reduce the occupant loads. The integrated safety concept incorporates pre-crash systems, occupant protection systems, and a CFRP monocoque, among other features, and was developed using numeric simulations. Verifiable proof of the operative function and benefit of the safety concept was provided by leveraging numerical simulation techniques, carrying out comprehensive component tests, and conducting a series of full-scale crash tests using a Visio.M prototype. In the end, the integrated safety strategy is the key to realizing a sufficient level of protection for sub-compact vehicles.

PAPERNO.15-0246-O

Occupant Protection in Rear-End Collisions Preceded by Autonomous Emergency Braking Deployment

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TASS International, Netherlands

ABSTRACT

The safety of vehicle occupants has evolved recently due to the market implementations of new sensing technologies that enable predicting and identifying hazardous road traffic situations and thus actively prevent or mitigate collisions. The obvious benefits of the active safety systems has also been recognized and acknowledged by the regulatory and consumer bodies responsible for transportation, and as a result, the new standards, regulations and public rewards are being introduced.

The active safety systems can prevent or mitigate collisions by controlling the motion of the vehicles through autonomous actuation of either: braking, steering or both simultaneously. The autonomous control of the vehicle inevitably affects the motion of the travelling occupants with respect to the vehicle interior. Depending on the severity of the maneuver, the occupant motion may lead to non-optimal postures for the in-crash phase if the collision is unavoidable. This consideration creates the direct need for developing the active systems together with passive systems with the ultimate objective to best protect the occupants. This paper presents a simulation methodology for developing new automotive safety systems in an integrated manner that ensures optimal exploitation of benefits of predictive sensing and occupant restraints. It also demonstrates the application of the above methods, to investigate and optimize the occupant whiplash protection in rear-end collisions occurring during the autonomous emergency braking of the collided vehicle.

The investigation was performed using simulation techniques (MADYMO software). The driver occupant is initially exposed to the low-g longitudinal acceleration resulting from emergency braking, during which the rear-end acceleration pulse is applied, representing the collision conditions (following the High Severity Sled Pulse of Euro NCAP Whiplash testing protocol). Two different models of anthropometric test devices are used and compared: BioRID-II facet Q model and Active Human Model (AHM) to predict occupant motion while braking and assess injury risk as a result of the rear-end collision.

The results obtained showed the severity of the out-of-position occupant posture created by the autonomous braking maneuver, and its effect on injury risk in the consecutive collision. It was observed that the occupant motion resulting from braking is more pronounced in case of AHM than BioRID-II. Increased occupant travel during pre-braking impairs significantly the effectiveness of occupant rear-end protection restraint systems, thus increasing the whiplash injury risk. Further study demonstrates conceptual, pre-crash deployed safety solutions that alleviate the negative effects of the out-of-position postures created by pre-braking.

The study shows the need for developing the new safety systems in an integrated manner. It was performed based on the numerical simulations and some of the model components were not fully validated. The simulation methods and techniques will play a significant role in the integrated safety systems development processes, allowing testing the conditions of high complexity in order to represent the real life scenarios and thus ensuring better occupant protection.

PAPER NO.15-0137-O

Ecall – Defining Accident Conditions for Mandatory Triggering of Automatic Emergency Calls

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ABSTRACT

eCall, the pan-European automatic crash notification system, will facilitate road vehicles to contact emergency services autonomously when a potentially injurious crash has been detected by vehicle sensors. Type-approval requirements will set out conditions for assessing systems under which automatic triggering of eCalls will be mandatory. Research is needed to specify the accident typologies and severities represented by these conditions.

This paper analyses what definition of accident conditions would ensure that a high number of casualties benefit from automatic eCalls. The conditions should also allow cost-effective type-approval testing, avoid excessive numbers of superfluous eCalls, and not restrict manufacturer's design freedom.

Two conditions were considered as being particularly suitable for the European type-approval system:

- Condition A: Trigger in accident conditions similar to, and at least as severe as, a mandatory frontal or lateral full-scale crash test.
- Condition B: Trigger in conjunction with deployment of any airbag.

In-depth accident data from the Road Accident In-Depth Studies (RAIDS) database, collected between 2000 and 2010 for the Co-operative Crash Injury Study (CCIS), was analysed to produce an estimate of the proportion of car occupant casualties captured by each of these conditions and subsequently scaled to a national level for Great Britain.

The analysis found that Condition A captured only 34.7% of fatally and seriously injured casualties whereas Condition B would apply to 81.0%. For Great Britain, with about 9,335 fatally or seriously injured car occupants annually, this is a difference of 4,330 fatal or serious casualties which could benefit from automatic eCall triggering each year. However, if Condition B was applied, automatic eCalls would be triggered for 74,390 slight casualties per annum in GB (and for an additional unknown number of damage-only accidents).

The sensitivity of Condition B, i.e. the proportion of casualties successfully selected, is considerably higher compared to Condition A. Nevertheless, accident types where airbags are deliberately not deployed would not be captured. Condition B exhibited an almost unvaryingly high sensitivity in selecting fatal casualties and serious casualties respectively.

The higher sensitivity of Condition B is achieved at the expense of specificity in selecting fatal or severe casualties, i.e. more of the collisions for which an eCall is triggered would be slight casualties. There are indications, however, that the negative consequences of superfluous eCalls could be mitigated.

The results are based on British data and cannot be transferred in detail to other countries. The general trends identified would be expected to also appear in reproductions of this analysis using data from other European countries.

The most preferable mandatory automatic eCall triggering condition for type-approval legislation appears to be triggering in conjunction with deployment of any airbag. Nevertheless, up to 19.0% of fatal and serious car occupant casualties might not be captured by this condition. To allow this problem to be overcome using advanced triggering algorithms, a non-restrictive approach could be taken with regard to the triggering requirement, i.e. require triggering in the presence of the condition yet not prohibit triggering in its absence.

PEER REVIEW: PAPERNO.15-0147-O

Estimated Injury Risk for Specific Injuries and Body Regions in Frontal Motor Vehicle Crashes

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ABSTRACT

Research Question/Objective

Injury risk curves can be used to estimate the risk of motor vehicle crash (MVC) occupant injury from event data recorder (EDR) measurements such as crash speed and restraint status. EDR data can be used in advanced automatic crash notification (AACN) algorithms to predict occupant injury immediately following a MVC and inform first responders and patient care providers of triage recommendations and suspected injuries. The goal for this study was to use EDR measurements defined in Part 563 regulation to compute occupant injury risk for 1) specific injuries and 2) specific body regions in frontal MVCs from weighted National Automotive Sampling System – Crashworthiness Data System (NASS-CDS) data.

Methods and Data Sources

Logistic regression analysis of NASS-CDS single impact frontal MVCs involving front-seat occupants with frontal airbag deployment was used to produce 23 risk curves for specific injuries and 17 risk curves for AIS 2+ to 5+ body region injuries. Risk curves were produced for the head and thorax (AIS 2+, 3+, 4+, 5+), face (AIS 2+), abdomen, spine, upper extremity, and lower extremity (AIS 2+, 3+). Longitudinal delta-v and belt status were controlled for in the models and 95% confidence intervals were computed for each belted and unbelted risk curve.

Results

Overall, belted occupants had lower estimated risks compared to unbelted occupants and risk of injury increased with longitudinal delta-v. At a 56 kph longitudinal delta-v analogous to FMVSS 208, 18 (78%) of the 23 injuries had a higher injury risk for unbelted compared to belted occupants (average risk: 146.3% higher). Risk for unconsciousness, subarachnoid hemorrhage, unilateral lung contusion, and fractures of the femur, fibula, tibia, patella, and pelvis was significantly higher for unbelted compared to belted occupants for select delta-v ranges where 95% confidence intervals were non-overlapping. Belted occupants had a higher risk at a 56 kph longitudinal delta-v for sternum, lumbar transverse process, carpus/metacarpus, clavicle, and radius fractures (average risk: 115.1% higher). All of the body region risk curves except the AIS 2+ and 3+ spine curves had delta-v ranges where the unbelted risk was significantly higher than belted risk. For example, unbelted risk was significantly higher up to a 73 kph longitudinal delta-v for AIS 2+ head injuries and up to a 39-51 kph longitudinal delta-v for AIS 3+, 4+, and 5+ head injuries.

Discussion and Limitations

These risk curves were developed for an AACN algorithm that also estimates the overall risk of serious occupant injury. Including additional variables could improve risk prediction, but this study utilized only EDR measurements specified in regulation.

Conclusion and Relevance to session submitted

When implemented into an AACN algorithm, these injury risk curves will provide EMS and patient care providers with information on injuries that a given occupant is suspected to have sustained in a MVC. This additional information could lead to improved detection of specific injuries, better triage decisions on where to transport an occupant (trauma center versus non-trauma center), and a reduction in the time that elapses before an injured occupant receives definitive treatment.

PAPERNO.15-0167-O

Utilization of Crash Scene Photography Documenting Vehicle Damage and Intrusion to Improve Trauma Care Preparedness

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ABSTRACT

Objective

To design, develop, and field test a smartphone app (called TraumaHawk) that would transmit photographic vehicle crush information to a trauma center in advance of patient arrival, then determine whether such information increases the amount of lead time the trauma center has to activate and prepare for treating crash injured patients.

Methods

TraumaHawk, a smartphone app for law enforcement and first responders, was designed by the University of Iowa to send photographs showing extent of intrusion and vehicle damage in a vehicle's occupant compartment to the receiving trauma center. With some basic training, first-responders and law enforcement personnel were taught how to photograph vehicles at a crash scene; trauma staff similarly received training regarding crash injury biomechanics and traumatology. For TraumaHawk cases received October 2013–August 2014, electronic medical records and trauma team notification pages were examined. Time of notification and actual time of patient arrival were noted. Time of TraumaHawk alert for these cases was also recorded. Traditional paging and TraumaHawk lead-times (minutes) were calculated. A paired t-test was used to determine if the mean lead-times for the Paging and TraumaHawk alerts differed significantly.

Results

During the study period, 35 TraumaHawk cases were identified, and 32 met trauma team activation criteria. For these 32, actual mean time between the trauma team page and patient arrival was 12 min; for TraumaHawk, advance notice was received at the trauma center 26 minutes before patient arrival, more than doubling notification time ($p<0.001$).

Conclusions

Utiltizing TraumaHawk to identify serious crashes remotely allowed the trauma team significantly more time to prepare for incoming trauma patients than the conventional ambulance crew notification. This allotted time allowed trauma staff to assemble a more complete and appropriate level of care by specialists, as well as to arrange other vital aspects of care—such as scheduling operating rooms.

Keywords: Motor vehicle crashes, traumatic injury, injury mechanism, prehospital

PAPERNO.15-0190-O

Occupant Transportation Decision Algorithm: An Advanced Automatic Crash Notification Algorithm Developed and Evaluated for Motor Vehicle Crash Occupant Triage

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ABSTRACT

The objective was to develop an Advanced Automatic Crash Notification (AACN) algorithm and evaluate its performance in making optimal occupant triage decisions. The developed AACN algorithm known as the Occupant Transportation

Decision Algorithm (OTDA) uses measurements obtainable from vehicle telemetry to predict risk of overall occupant injury and recommend a transportation decision for the occupant following a motor vehicle crash (MVC), particularly whether transport to a Level I/II trauma center is recommended. A list of injuries necessitating treatment at a Level I/II trauma center (TC) was determined using an injury-based approach based on three facets (severity, time sensitivity, and predictability). These three facets were quantified for each injury from expert physician and emergency medical services (EMS) professional opinion and database analyses of the National Trauma Data Bank and National Inpatient Sample. Severity, Time Sensitivity, and Predictability Scores were summed for each injury to compute an Injury Score. Injuries with an Injury Score exceeding a particular threshold were included on the Master Target Injury List, which is a list of injuries more likely to require Level I/II TC treatment. OTDA inputs for development include the Master Target Injury List and 38,970 National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) 2000-2011 occupants. The OTDA uses multivariate logistic regression to predict an occupant's risk of sustaining an injury on the Master Target Injury List from the following model variables: longitudinal/lateral delta-v, number of quarter turns (in rollover only), belt status, multiple impacts, and airbag deployment.

A parametric OTDA was developed with five tunable parameters allowing for extensive optimization. The OTDA was optimized with a genetic algorithm that compared the OTDA transportation decision for each NASS-CDS occupant to a dichotomous representation of their Injury Severity Score (ISS). Occupants with ISS 16+ should be transported to a Level I/II TC. OTDA optimization minimized under triage (UT) and over triage (OT) rates with the goal of producing UT rates < 5% and OT rates < 50% as recommended by the American College of Surgeons (ACS). For the optimized OTDA, UT rates by crash mode were 5.9% (frontal), 4.6% (near side), 2.9% (far side), 7.0% (rear), and 16.0% (rollover). OT rates by crash mode for the optimized OTDA were 49.7% (frontal), 47.9% (near side), 49.7% (far side), 44.0% (rear), and 49.7% (rollover).

The OTDA was developed with an injury-based approach that examined three injury facets to identify injuries necessitating treatment at a Level I/II TC. Large hospital and survey datasets containing information on injuries, mortality risk, treatment urgency, and hospital transfers were used in conjunction with large crash datasets with crash, vehicle, occupant, and injury data. The OTDA has been rigorously optimized and has demonstrated improved UT rates compared to other AACN algorithms in the literature and OT rates meeting ACS recommendations. Since the OTDA uses only vehicle telemetry measurements specified in Part 563 regulation, this AACN algorithm could be readily incorporated into new vehicles to inform emergency personnel of recommended triage decisions for MVC occupants. The overall societal purpose of this AACN algorithm is to reduce response times, increase triage efficiency, and improve overall patient outcome.

PAPERNO.15-0388-O

Results from First Field Test of Telemetry Based Injury Severity Prediction

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ABSTRACT

Identification of severely injured occupants is of utmost urgency following a crash event. Advanced automatic collision notification (AACN) has great potential to improve post-crash care if the risk of severe injury to a vehicle's occupants can be accurately predicted. The National Expert Panel for Field Triage set a 20% risk of Injury Severity Score (ISS) 15+ injury as the threshold for urgent transport to a trauma center. The objective of this study was to field test real world performance of the published injury severity prediction (ISP) algorithm in collisions involving recent model GM vehicles equipped with OnStar.

This study was approved by the IRB of the Michigan Department of Community Health. There were 924 occupants in 836 crash events, involving vehicles equipped with AACN capabilities, in the state of Michigan which were identified from the OnStar records. The police crash report corresponding to the event was identified in the State of Michigan database and used to confirm data sent by telemetry from the vehicle. The injury status of all occupants in the case vehicles was determined. Occupants not transported for medical evaluation were assumed to have ISS<15. For occupants transported from the scene for evaluation and treatment, medical records and imaging data were obtained from the treating facility. Case reviews were conducted to jointly analyze crash, vehicle telemetry, and injury outcome data. The algorithm was used to calculate the predicted risk of injury based on transmitted telemetry data and this prediction was compared to the observed injury outcome for each vehicle as well as each occupant.

In this field study, the ISP algorithm's ability to predict whether a vehicle had a seriously injured (ISS>15) occupant was, in terms of sensitivity, at 63.64% compared to the model sensitivity of 39.6% and it also came very close to expectations of specificity at 96.12% compared to the model specificity of 98.3% with use of age and gender data. Without use of age and gender, for ISP calculation, the sensitivity performance was 45.45% while the specificity improved slightly to 97.58%. Detailed analysis of cases suggests that further performance gains could be obtained with more detailed definition of crash direction, seating position, and occupant age.

There were 184 candidate crash occupants in 167 vehicles not included in the study analysis due to: A) missing Police accident reports, n=77 in 75 crashes; B) inability to retrieve medical records, n = 71 in 61 crashes; or C) rollover event, n=36 in 31 crashes. Analysis of these excluded cases did not reveal any bias in crash severity or injury that would confound the current study findings.

This study confirms for the first time under real-world field conditions that occupant injury severity can be predicted using vehicle telemetry data. The ISP algorithm's ability to predict a 20% or greater risk of severe (ISS15+) injury was better than anticipated and confirms ISP's utility for the field triage of crash subjects. This analysis suggests that AACN technology can greatly facilitate the collection of field data with ISP also serving as a baseline for potential monitoring of the benefits resulting from vehicle safety design changes.

PAPERNO.15-0415-O

Pilot Study on AACN and HEMS System in Japan

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ABSTRACT

This paper focuses on the pilot study on Advanced Automatic Collision Notification (AACN) and Helicopter Emergency Medical Service (HEMS) systems in Japan. The pilot study was carried out in Chiba prefecture by the AACN Committee in affiliation with Emergency Medical Network of Helicopter and Hospital (HEM-Net).

There were many opinions that Japanese accident data was preferable to develop a Japanese AACN algorithm. Then, the Occupant Injury Predict Algorithm newly developed by Nihon University was utilized for the study. About 2.8 million Japanese accident data (so called ITARDA Macro Data) were used to define logistic regression risk curves of fatal and severe injuries to car occupants. To validate this algorithm, the in-depth accident case study by Nihon University and Nihon Medical University at the Chiba Hokusoh Hospital was used. Moreover, to decide the threshold value, this in-depth accident study was also used.

Regarding the AACN prototype system, HELPNET infrastructures already developed for existing Japanese ACN service were used for sending vehicle data to the HELPNET center. In the simulated accident, Event Data Recorder (EDR) data was added on usual HELPNET data and transmitted from a car to a HELPNET server at the HELPNET center. The AACN server got vehicle data such as Delta V and seatbelt status as input to the algorithm.

The result was transmitted to a Tablet PC at the Fire Department Head Quarters and Chiba Hokusoh hospital simultaneously. An operator of HELPNET made an Emergency Call to both the Fire Department and Hokusoh hospital individually.

In case of severe injury, a Tablet PC indicated the situation and a doctor dispatched to the accident spot by a helicopter. After a helicopter with a doctor took off, verbal communications between the helicopter and Fire Department started to decide a rendezvous point nearby the crash spot. After landing, the doctor contacted the injured occupant who was carried by an ambulance there. The AACN prototype system for a limited area, only in Chiba prefecture, was developed.

AACN transmitting tests were carried out at some spots in Chiba prefecture within the jurisdiction of two headquarters individually. The prototype AACN system operated as intended. Within a minute from the airbag deployment signal, the algorithm result screen arrived simultaneously on AACN Tablet PCs at Chiba Hokusoh hospital, Chiba prefecture Fire Department H.Q. and also at the transmitting spot. The next step of AACN transmitting test should be that AACN activates HEMS of Chiba Hokusoh hospital. To expand cover area in Japan, collaborations of other HEMS base hospitals in other prefectures should be planed soon.

PAPERNO.15-0427-O

Assessing Mechanisms of Injury as Predictors of Severe Injury for Adult Car and Truck Occupants

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ABSTRACT

This study evaluates Mechanisms of Injury (MOI) that can be rapidly assessed at the scene of accident and may be used as predictors of severe injury for traffic accidents involving occupants in cars or trucks. The objective is to increase the knowledge of how MOI can be used to differentiate whether a patient is severely injured or not. This knowledge can be used to improve trauma triage systems. Furthermore, an objective is to analyze safety differences between cars and light/heavy trucks. The scope is adult occupants of cars, light and heavy trucks injured in accidents registered in the Swedish Traffic Accident Data Acquisition (STRADA) database from 2003 to 2013. Partition between severe and non-severe injury was done according to the Injury Severity Score (ISS) with ISS > 15 as definition of severe injury. The MOIs considered were: belt use, airbag deployment, posted speed limit, elderly occupant (age $\geq$ 55 years), sex, type of accident (single, intersection, turning, head-on, overtaking, rear end, tram/train, wild animal or other) and location of the accident (urban or rural). The different MOI were evaluated individually using univariate chi-square tests and together using multivariate logistic regression models. Results show that belt use is the most crucial factor determining risk of severe injury for all vehicle types. Age is the second most important factor, with elderly occupants exhibiting a higher risk. Head-on accidents are the most dangerous for cars and light trucks while single accidents are the most dangerous for heavy trucks. Belt use compliance is much lower for truck occupants. This appears to be the main reason for the frequency of severe injury being higher for truck occupants than for car occupants.

Assessment of New and Improved Field Data Collection, Analysis and Benefits Assessment Methods

Thursday, June 11, 2015 | 8:30 a.m.- 12:30 p.m.
Chairperson: Robert Thomson, Sweden| Co-Chair: Bernd Lorenz, EEVC | TRACK C | Room: F1-F2

PaperNo.15-0124-O

Features of Car–Cyclist Contact Situations in Near-Miss Incidents Compared with Real-World Accidents in Japan

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ABSTRACT
The use of active safety devices that can detect cyclists is considered an effective countermeasure for the reduction of the severity of injuries and number of deaths of cyclists. The detailed features of car–cyclist contact scenarios need to be clarified to develop such safety devices. Because there is limited information on real-world accidents, the present study investigates near-miss scenarios captured by drive recorders installed in passenger cars.
The first purpose of the present study is to ascertain the utility of using near-miss scenarios in clarifying the features of situations of contact between cars and cyclists. The similarities of data of near-miss incidents including video captured by drive recorders and national data of real-world fatal cyclist accidents in Japan are investigated. We used 229 videos of near-miss car–cyclist incidents collected by the Society of Automotive Engineers of Japan (J-SAE) from 2005 to 2009. In scenarios where the car travels straight ahead, 70–84% of cyclists on straight roads or at intersections crossed the road in front of the forward-moving cars both in accidents and near-miss incidents. There are thus similarities between accidents and near-miss incidents and it is possible to estimate the situations of cyclists' accidents from near-miss incident data including video that captures cyclist behavior.
The second purpose of the study is to calculate the time to collision (TTC) from the near-miss incident data. The study analyzed data for 166 near-miss car–cyclist incidents in which cyclists crossed the road in front of forward-moving cars on straight roads or at intersections. We calculated the TTC from the velocity of the car with an installed drive recorder and the distance between the car and the cyclist at the moment the cyclist appeared in the video captured by the drive recorder. The average TTC was 2.1 s (Standard Deviation (SD) of 1.6 s). In terms of the manner in which cyclists emerged in front of cars, the average TTC was the shortest (1.9 s) when cyclists emerged from behind a building or moving vehicle in the opposite lane. We propose that the specifications of a safety device developed for cyclist detection and automatic braking should reflect detailed information that includes the TTC obtained for near-miss situations.

PEER REVIEW: PAPERNO.15-0110-O

Differences in Long-Term Medical Consequences Depending on Impact Direction Involving Passenger Cars

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ABSTRACT

Research Question/Objective

The objective was to evaluate if injuries leading to permanent medical impairment differ depending on impact direction.

Methods and Data Sources

In total, 36,743 injured occupants in car crashes that occurred between 1995 and 2011 were included. All initial injuries (n=61,440) were classified according to the Abbreviated Injury Scale (AIS) 2005. Injured car occupants were followed for at least 3 years to assess permanent medical impairment. The data were divided into different groups according to impact direction and levels of permanent impairment. The risk of permanent medical impairment was established for different body regions and injury severity levels, according to AIS.

Results

It was found that almost 12% of all car occupants sustained a permanent medical impairment. Given an injury, car occupants involved in rollover crashes had the highest overall risk to sustain a permanent medical impairment. Half of the head injuries leading to long-term consequences occurred in frontal impacts. Far-side occupants had almost the same risk as near-side occupants. Occupants that sustained a permanent medical impairment from cervical spine injuries had similar risk in all impact directions (13%) except from rollover (17%). However, these injuries occurred more often in rear crashes. Furthermore, most of the injuries leading to long-term consequences were minor injuries (AIS 1).

Discussion and Limitations

In order to describe the consequences of vehicle collisions, an injury rating using the AIS system is a common method of measurement. AIS 3+ is often specified as a relevant level of injury. By applying the same method on this data set, 95 percent of injuries leading to permanent medical impairment would not have been detected because they were classified as AIS 1 and AIS 2. Even though the risk of injuries leading to permanent medical impairment was low for AIS 1 injuries, injuries of this level are very frequent, thus comprising the majority of injuries leading to permanent medical impairment.

Conclusion and Relevance to session submitted

Studying crash data from a perspective of medical impairment is important to identify injuries that might not be prioritized only considering the AIS-scale, but might lead to less quality of life for the occupant and also costs for society. These results can be used for road transport system strategies, and for making priority decisions in vehicle design.

PAPERNO.15-0394-O

Analysis and Simulation of Occupant Injury Risk at NASS/CDS

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ABSTRACT

The body regional injury information from the head, thorax, abdomen, upper and lower extremities of vehicle occupant due to the restraints and interior parts were extracted from 2009-2012 NASS/CDS data base. For those cases with high occurrence frequency, detailed and comprehensive data analysis was performed to find significances between the

accident, occupant, vehicle, and injury data. A numerical frontal impact sled model with Hybrid III dummy and GHBMC human body model is constructed to simulate and identify those injury risks at NASS/CDS.
Among the 5,734 body regional injuries from frontal crash accidents, lower extremity (27.8%), upper extremity (21.3%), thorax (15.1%), face (10.9%), spine (8,7%), head (7.3%), and abdomen (6.9%) were found in order of frequent occurrence. The main injury sources of the head were windshield, side structure, and steering wheel. For thorax and abdomen, they were seat belt and steering wheel. Instrument panel was for the lower extremity. Body regional injury patterns for head were concussion and contusion. For thorax, they were vessel laceration and lung contusion. For abdomen, laceration and contusion of organs were major injury patterns. Bone fracture and ligament rupture were found at the lower extremity. Steering wheel and seat positions were main factors affect head and thorax injury risks. From the sled impact simulation, high injury risks of the head and thorax were assessed respectively at conditions of steering column tilt down and rear most seat positions, which correlated well with the findings at NASS/CDS data analysis.

PAPERNO.15-0168-O

Mathematical Modelling and Numerical Optimization of Three Vehicle Crashes Using a Single-Mass Lumped Parameter Model

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ABSTRACT
In this paper mathematical modelling of a vehicle crash based on a lumped parameter model is studied. The vehicle is modelled as a single mass connected to a non-linear spring and damper system. The characteristics of the non-linear behaviour of the model is identified with a hybrid Firefly/Harmony Search optimization algorithm that minimizes the deviation between experimental test data and a simulated response. The experimental data is taken from three crashes of an identical vehicle that crashes into a wall at different initial velocities. The aim of this paper is to find a piecewise-linear function for the spring and damper coefficients which is scaleable to reconstruct the three different experimental crashes at different impact velocities. Numerical results are provided to illustrate the applicability of the proposed algorithm. Three data sets will be used for parameter identification and a fourth data set will be used for verification.

PAPERNO.15-0291-O

Lives Saved by Vehicle Safety Technologies and Associated FMVSS

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ABSTRACT
NHTSA began in 1975 to evaluate the effectiveness of vehicle safety technologies associated with the Federal Motor Vehicle Safety Standards (FMVSS). By June 2014, NHTSA had evaluated the effectiveness of virtually all the life-saving technologies introduced in passenger cars, pickup trucks, SUVs, and vans from about 1960 up through about 2010. A statistical model estimates the number of lives saved from 1960 to 2012 by the combination of these life-saving technologies. Fatality Analysis Reporting System (FARS) data for 1975 to 2012 documents the actual crash fatalities in vehicles that, especially in recent years, include many safety technologies. Using NHTSA's published effectiveness estimates, the model estimates how many people would have died if the vehicles had not been equipped with any of the safety technologies. In addition to equipment compliant with specific FMVSS in effect at that time, the model tallies lives saved by installations in advance of the FMVSS, back to 1960, and by non-compulsory improvements, such as pretensioners and load limiters for seat belts. FARS data has been available since 1975, but an extension of the model allows estimates of lives saved in 1960 to 1974. A previous NHTSA study using the same methods estimated that vehicle safety technologies had saved 328,551 lives from 1960 through 2002. The agency now estimates 613,501 lives saved from 1960 through 2012. The annual number of lives saved grew from 115 in 1960, when a small number of people used

lap belts, to 27,621 in 2012, when most cars, light trucks, and vans were equipped with numerous modern safety technologies and belt use on the road achieved 86 percent.

PAPERNO.15-0266-O

Validating Vehicle Safety Using Meta-Analysis: A New Approach to Evaluating Vehicle Safety Technologies

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ABSTRACT
In a world of rapid developments in the field of vehicle safety, robust and reliable methods are essential to evaluate the safety effects in real traffic. Only with significant evidence-based findings can OEMs, governments and consumers act to encourage the most important systems. The Euro NCAP Validating Vehicle Safety using Meta-Analysis (VVSMA) consortium was assembled, comprising a collaboration of government, industry consumer organisations and researchers, using pooled data from a number of countries and the established MUNDS method. Technologies of immediate interest included low speed autonomous emergency braking (low speed AEB or AEB City), and Lane Departure Warning (LDW) technologies in current model passenger vehicles. Real-world crash data were assembled by 6 countries for the analyses and induced exposure methods were adopted to control for any extraneous effects. To date, the findings for AEB City technology found that while individual countries analyses failed to show significant reductions in crashes, robust statistically significant reductions were found overall from the meta-analysis due to the increase in the amount of data. The analysis for Lane Departure Warning technology is currently in process. Greater difficulty is experienced with evaluating this technology due to it only being available as optional equipment. The findings show how safety benefit analyses can be performed in a timely manner, using data from many countries in a meta-analysis procedure.

PAPERNO.15-0372-O

Extrapolation of GIDAS Accident Data to Europe

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ABSTRACT
In the paper it is investigated to what extend one can extrapolate the detailed accident database GIDAS (German In-Depth Accident Study), with survey area Hanover and Dresden region, to accident behavior in other regions and countries within Europe and how such an extrapolation can be implemented and evaluated. Moreover, it is explored what extent of accident data for the target country is necessary for such an extrapolation and what can be done in situations with sparse and low accident information in a target region.
It will be shown that a direct transfer of GIDAS injury outcomes to other regions does not lead to satisfactory results. But based on GIDAS and using statistical decision tree methods, an extrapolation methodology will be presented which allows for an adequate prediction of the distribution of injury severity in severe traffic accidents for European countries. The method consists essentially of a separation of accidents into well-described subgroups of accidents within which the accident severity distribution does not vary much over different regions. In contrast the distribution over the various

subgroups of accidents typically is rather different between GIDAS and the target. For the separation into the subgroups meaningful accident parameters (like accident type, traffic environment, type of road etc.) have been selected. The developed methodology is applied to GIDAS data for the years 1999-2012 and is evaluated with police accident data for Sweden (2002 to 2012) and the United Kingdom (2004 to 2010). It is obtained that the extrapolation proposal has good to very good predictive power in the category of severe traffic accidents.
Moreover, it is shown that iterative proportional fitting enables the developed extrapolation method to lead to a satisfactory extrapolation of accident outcomes even to target regions with sparse accident information. As an important potential application of the developed methodology the a priori extrapolation of effects of (future) safety systems, the operation of which can only be well assessed on the basis of very detailed GIDAS accident data, is presented.
Based on the evaluation of the presented extrapolation method it will be shown that GIDAS very well represents severe accidents, i.e. accidents with at least one severely or fatally injured person involved, for other countries in Europe. The developed extrapolation method reaches its limits in cases for which only very little accident information is available for the target region.

PAPERNO.15-0368-O

Analysis of Different Types of Winter Tires in Rear-End Injury Crashes and Fatal Loss-Of-Control Crashes with ESC

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ABSTRACT

This study aimed to compare studded and non-studded winter tyres with regard to the risk of being the striking car in rear-end injury crashes with passenger cars. A further aim was to evaluate the risk for a passenger car equipped with Electronic Stability Control (ESC) to be involved in a fatal loss-of-control (LOC) crash with studded and non-studded winter tyres. This research was based on two different materials. The study on rear-end crashes used police reports from crashes in Sweden between 2008 and 2014. The study was limited to crashes occurring in the winter period, in this study defined as October through to March. Only car-to-car two vehicle crashes were included (n=4239). As tyre information was not included in the police reports, a survey form was sent to all drivers asking which type of tyres was fitted on their car at the time of the crash. In total, 717 drivers (17%) responded. The relative risk for being the striking or struck vehicle, depending on winter tyres, was calculated using an induced exposure approach. The analysis of fatal crashes in the winter period used in-depth studies of fatal crashes collected by the Swedish and Norwegian Transport Administrations in the winter period between 2003 and 2014. Cars fitted with ESC (n=44) were compared with cars without ESC (n=260). The odds ratio for being involved in a LOC-crash was calculated depending on the ESC fitment and fitment of different winter tyres. The findings showed that the risk for being the striking vehicle in a rear-end injury crash on ice or snow was at least 27% higher for non-studded winter tyres, compared to studded tyres. With regard to all road conditions, no significant difference between winter tyres with or without studs were found. As the proportion of ice and snow differs greatly in different parts of Sweden, the overall estimated effect was significant in northern Sweden but not in mid or southern Sweden. The risk of a fatal LOC-crash was 65% lower with studded tyres compared with non-studded winter tyres for cars without ESC. In ESC cars, the risk reduction, compared to cars without ESC, was 92% including all types of winter tyres, which were grouped together due to the limited size of the material. The rear-end crash analysis was based on a material with a rather limited response frequency. Hence, the representativeness of the results should be treated with caution. Regarding the fatal crashes it could be concluded that ESC is very effective in reducing LOC-crashes regardless of type of winter tyres. This is the first study that shows the effect of studded tyres

related to specific crash types and to different geographical regions in Sweden. Hence, the findings in this study can contribute to the ongoing discussion on reducing the proportion of studded tyres in Sweden due to environmental and health issues.

PAPERNO.15-0253-O

A Continuous Video Recording System on a Lap-Belt Equipped School Bus: Real-World Occupant Kinematics and Injuries during a Severe Side Impact Crash

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ABSTRACT
A loaded truck-tractor semitrailer severely impacted the side of a lap-belt-equipped large school bus in which 30 students, age 5 to 11 years, were riding. The crash investigation obtained on-board video and audio from the school bus recording system, which had four active cameras that recorded at 15 frames per second. A total of 55 minutes 39 seconds of video and audio was obtained, including over 15 minutes after the bus came to final rest. Qualitative descriptions of occupant motion during the crash sequence were documented based on the time sequence of vehicle motion, including kinematics of lap-belted pediatric occupants, occupant-to-occupant interactions, and occupant-to-vehicle interactions. Further, quantitative measurements of occupant motion were performed by tracking visible body regions such as the head or center of the pelvis using commercially available motion analysis software. Occupant injuries were coded using hospital medical records and according to the Abbreviated Injury Scale 2008 manual.

Injury severity was higher in the rear of the bus near the region of impact, maximum intrusion, and maximum lateral accelerations. The injury severity scores (ISS) ranged from 1 to 6 in the front of the bus and from 1 to 57 at the rear, including the one student seated at the rear of the bus who was fatally injured. Head injuries included several mild to moderate traumatic brain injuries. Lateral head translations and velocities were evaluated. The lateral head displacements toward the impacted side in the front of the bus were similar to those in the rear during the initial impact, but the head displacements for occupants in the rear of the bus were greater during the secondary and tertiary rebound motions toward alternating sides of the bus. Lateral head velocities relative to the bus interior were generally almost twice as high in the rear of the bus as in the front. In addition, the magnitude of whole body pediatric occupant motion in the absence of injury was notable. Further, loss of consciousness negatively affected occupants' ability to self-evacuate, even when subjects regained consciousness.

The qualitative and quantitative descriptions represent the first time that lap-belted school bus pediatric occupant motion during a crash has been documented from continuous onboard video recordings. This unique data source allows the rare correlation of occupant kinematics with crash severity and injury outcomes in living humans.

PAPERNO.15-0149-O

Comparison of Event Data Recorder and Naturalistic Driving Data for the Study of Lane Departure Events

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ABSTRACT
Naturalistic Driving Study (NDS) data are an important source for driver behavior data to design and evaluate autonomous vehicles and driver assistance systems. The number of serious crash events in NDS, however, is often small. As a result, surrogates such as "near crashes" or events identified using vehicle instrumentation are used with the

assumption that they are relevant to real crash events. The objective of this study is to determine if NDS crash and near-crash data are indeed representative of crash events. To examine this issue, we focused on one subset of crash events, lane departure events where the vehicle drifts out of its lane. These are the events most likely to be mitigated by lane departure warning systems.

Four naturalistic datasets that covered the full range of events from lane departures during normal driving, to near-crashes, to crashes were compared to data from a crash database. Our hypothesis is that the crash and near-crash NDS events will have the most similar vehicle kinematics compared to the crash database. Normal driving departure events were extracted from the Integrated Vehicle-Based Safety Systems (IVBSS) field operation test. Two departure event datasets from IVBSS were identified using the lane tracking cameras. The first dataset consisted of 12,760 cases of the vehicle departing and returning to its lane and the second consisted of 7,750 events where the equipped LDW systems were triggered. Thirty-two (32) near-crash lane departure events were analyzed from the 100-Car NDS. Finally, 49 curb strike events were analyzed from the SHRP-2 NDS. Data from lane departure crashes was extracted from the National Automotive Sampling System, Crashworthiness Data System (NASS/CDS). Event Data Recorders (EDRs) downloaded from 482 NASS/CDS crash investigations were analyzed.

There were important sampling differences between datasets. Younger drivers were overrepresented in the 100-Car near-crash and SHRP-2 curb strike events and crash data while the IVBSS participants were uniformly distributed over age and gender groups. The vehicle speeds from IVBSS were restricted to over 42 kph (25 mph), whereas the crash data had vehicles speed that contained both low and high speed events. The 100-Car near-crash and SHRP-2 curb strike departures had larger departure angles (2.6° and 14.1° median, respectively) and lateral excursion (0.63 m and 0.50 m median, respectively) compared to the IVBSS data (0.6° and 0.7° departure angle and 0.19 m and 0.10 m excursion for LDW and lane departure datasets, respectively). The differences in departure conditions may have also affected driver maneuvers after the departure. In 52% of crashes with EDRs there was a brake application in the last second before the crash compared with 38% of 100-Car near-crash and 33% of SHRP-2 curb strike events. The selection criteria for the IVBSS departures excluded almost all brake application, with only 4% of the IVBSS LDW events having brake application. Steering wheel input was also substantially larger in the 100-Car near-crashes (48°) compared to the IVBSS (4°-5°).

PAPER NO. 15-0133-O

Analysis of Quad-Bike Loss-Of-Control Caused by Bump Perturbations Using Experimental and Simulated Dynamic Bump Tests

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ABSTRACT

Quad-bikes, also known as all-terrain vehicles in the United States of America, continue to be a major contributor to fatal and serious injuries in Australia as well as in many other countries all over the world, both for recreational use and in the workplace. There have been over 150 fatalities caused by quad-bike incidents in Australia since 2000 with around 70 percent of these attributed to rollovers. In 2011, quad-bikes overtook tractors as the leading cause of injury and death on Australian farms.

There is a significant portion of quad-bike fatalities that are identified as being caused by riding over a raised obstacle (i.e. bump, log, tree stump, etc.), which causes the vehicle to lose control and rollover. However, the authors are not aware of any research that has been published to date in regards to identifying the mechanism that causes this loss-of-control situation in the case of quad-bikes. This paper details a novel method used to identify this mechanism.

Preliminary testing conducted with a human test rider, identified that a rider can be significantly displaced across the seat when riding a quad-bike over a semi-circular raised obstacle placed on one side of the vehicle wheel track. A formal test procedure was then developed to measure the pelvis kinematics of an Anthropomorphic Test Device mounted on a quad-bike moving over a 150mm high bump obstacle placed on one side of the vehicle wheel track. This procedure was then simulated using a Finite Element (FE) model of a quad-bike that was validated against experimental tests. The analysis of both experimental and FE simulation results presented here clearly demonstrate how a quad-bike loss-of-control event, leading to rollover, can be triggered by a bump-like raised obstacle.

PAPERNO.15-0284-O

Opportunities for Injury Reduction in Rollover Crashes

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ABSTRACT

The NASS/CDS remains the best US data source for understanding the magnitude of the opportunities for reducing rollover injuries to the various body regions. However, judicious analysis techniques are required to address the many confounding factors, including but not limited to the consequence of recent safety improvements such as electronic stability control and increased roof strength. To better assess the effect of recent safety improvements, the population of drivers in rollovers in light vehicles model year 2000 and later was examined. To address crash severity, the number of quarter-turns was used. Injuries were separated by body region and the HARM method of aggregating injuries was used to provide added weighting to the more severe injuries. For belted drivers in near-side rollovers, the fourth quarter-turn contained the most HARM and the highest injury risk, especially for chest injuries. For belted drivers in far-side rollovers, most of the chest injury HARM is fairly uniformly distributed between quarter-turns 2, 4, 6 and 8.

Written Papers

Protection of Vulnerable Road Users

Chairperson: Suzanne Tylko, Canada; Jim Hand, United Kingdom

PAPER NO. 15-0111-W

Active Hood Pedestrian Protection

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ABSTRACT

Objective: One means of protecting pedestrians is through vehicle safety systems that are built into a vehicle's front-end to protect pedestrians should a vehicle impact occur. These pedestrian protection systems include hood structures aimed at reducing pedestrian head injuries. Pop-up hoods function by increasing the head penetration space beneath the hood by quickly lifting upon vehicle contact with a pedestrian. This paper explores the prevalence of vehicles with pop-up hoods to show that their market penetration and performance benefits merit consideration in standardized pedestrian protection test protocols.

Methods: Euro NCAP test scores and the Parkers United Kingdom (UK) vehicle database were used to better understand the fleet performance and market penetration of vehicles with pop-up hoods. An analysis of Euro NCAP pedestrian test results and overall vehicle test scores was performed to compare the performance of vehicles equipped with pop-up hoods to those without, and the Parkers UK vehicle database was used to estimate historical vehicle prices and demonstrate that pop-up hoods are available on both high- and low-cost vehicles.

Results: There are many different types of systems that operate pop-up hoods, and their architectures vary widely from one vehicle to the next; however, they typically create an increase in the distance from the hood to rigid components in the engine bay, thus reducing the probability and/or severity of a head injury of a struck pedestrian. Compared to vehicles with non-deploying hoods, vehicles with pop-up hoods rated by Euro NCAP had better pedestrian protection scores on average. In the European Union (EU), pop-up hood systems, which have become more prevalent over time, were found on vehicles outside the oft-assumed market of only low-volume luxury models.

Discussion and Limitations: Pedestrian Protection is mandatory on all vehicles sold in the EU Conformity of pop-up hoods is based largely on headform impact tests conducted on a fully popped-up hood. During the Type Approval process, the determination of system reliability and consistency also must be demonstrated by the vehicle manufacturer, but the means and requirements to do so are not defined within the regulation itself. Because the operation of pop-up systems varies widely and they are generally unique to specific vehicle models, the demonstration of system functionality is agreed upon between the manufacturer and the Type Approval Authority. Euro NCAP operates in a similar manner.

Conclusions: Pop-up hoods generally perform better than non-deploying hoods in headform impact tests. As their development matures and vehicle styling progresses towards low, sleek, aerodynamic hood profiles, demand as well as variation in these systems may grow. To date there is not a published, fully prescriptive test protocol that tests the full functionality of such systems, including reliability and deployment thresholds, to objectively ensure that they function properly during an actual collision with a pedestrian.

PAPERNO.15-0175-W

Analysis of Children Strollers and Prams Safety in Urban Buses

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ABSTRACT

The wide incorporation of low floor buses in our cities encourages that child younger than three years, seated on their stroller could use the buses. Currently, the UNECE Regulation No 107 at its revision 5 has included general provisions for the accessibility and basic safety for this type of users. An applied research has been performed to analyze the level of protection offered for the stroller restraint systems included in R107, by performing dynamic tests with instrumented dummies.

More than 20 dynamic sled tests were performed to assess the child safety in urban buses. Two types of configurations have been tested: a vehicle specific CRS for urban buses and the own stroller with different restraint systems.

The specific vehicle built-in CRS tested is a rearward facing group 0/I that is currently in use in the city of Madrid (Spain) by the public urban buses. This CRS was tested in frontal and rear impact with the acceleration pulse defined in the UNECE regulation No 80.

On the other hand, to make suggestions for using the stroller in urban buses, a very low severity crash pulse (up to 2 g peak acceleration and ΔV = 20 km/h) was defined and used in this study. Four stroller models with three types of restraint devices (safety belt, PRM wheelchair backrest and a folding backrest device) were tested with this pulse. The strollers were selected in order to reduce biasing of the results. Several dummies (P3, Q3 and Q1) were used to evaluate the injuries and the kinematics. Furthermore, different sources of IRAV have been applied for the Q dummies (R94 and FMVSS 208 scaled by applying Mertz 2003 techniques), an extended range of injury criteria is obtained and an in depth analysis of the protection offered by the different restraints systems used is performed.

PAPERNO.15-0177-W

Performance Comparison and Repeatability Evaluation of the Flex PLI and TRL Pedestrian Legform Impactors

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ABSTRACT

The objectives of this study were to compare the response differences of the Flex PLI and TRL legforms under various test conditions and to assess their repeatability. A test fixture with four control factors was designed and fabricated to simulate a generalized front structure of a light truck. Using this fixture, thirty-six impact tests with the Flex PLI and the TRL legforms were performed at an impact speed of 32 km/h.

The responses from the two legform impactors, specifically, moments in the Flex PLI and acceleration in the TRL, MCL elongation in the Flex PLI and bending angle in the TRL, and ACL elongation in the Flex PLI and shear displacement in the TRL were compared. The Taguchi method was applied to compare the responses from these three pairs of measurements. The shape and magnitude of the response time histories were used to evaluate the repeatability of the Flex PLI and TRL legforms.

Some results from this limited study indicate that the two legforms did not consistently respond to the same test conditions in the same way and could potentially drive countermeasures in opposite directions. For example, increasing the protrusion of the lower bumper stiffener relative to the bumper generally resulted in lower moments in the upper tibia with the Flex PLI, but higher accelerations with the TRL legform. However, the MCL from the Flex PLI and bending angle of the TRL legform trended consistently with changes of all four fixture factors, although with differing sensitivity.

A repeatability analysis indicated that most measurement parameters of each legform were repeatable or marginally repeatable across the spectrum of the test conditions. However, the MCL elongation of the Flex PLI and the bending angle of the TRL were non-repeatable in some test conditions.

PAPERNO.15-0243-W

Bicycle-To-Car Accidents - Their Consequences for the Bicyclists and Typical Accident Scenarios

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ABSTRACT

The structure of the official German statistics does not permit in-depth analyses to be carried out, so the UDV built up a set of representative case material in order to examine accidents between cars and cyclists in more detail and derive effective measures to improve the safety of cyclists. This material was formed from accidents with personal injury from the years 2002 to 2010 that were covered by motor third-party insurance and involved injury and damage costs of 15,000 euros or more. The cyclist accident material consists of a total of 407 accidents between cars and cyclists. This paper describes how and under what circumstances cyclist-car accidents occur, the maximum levels of injury severity sustained by the cyclists and the impact constellations that occur particularly frequently. In 84% of the cases, the impact between the bicycle and the car occurred at the front part of the vehicle (the front of the car plus the left- and right-hand front wings). In 42% of these cases, the bicycle was coming from the right (as seen by the driver), and in 34% of the

cases from the left. Moreover, the analysis of the cyclist-car accidents revealed that the average speed of the cars was a relatively low 24 km/h. The speed of the cyclists often could not be ascertained from the available documents. However, it is known from the UDV's measurements of the speeds of 20,000 cyclists that they travel at an average speed of 18.6 km/h. Three typical scenarios were obtained from the accident material that together account for 42% of all cyclist-car accidents. These three scenarios are "car traveling straight ahead, cyclist coming from the right" (15%), "car turning right, cyclist coming from the right" (15%) and "car traveling straight ahead, cyclist coming from the left" (12%). Another key finding is that the collisions in these three scenarios often (in 47% to 85% of the cases) took place at the entries to or exits from properties or parking lots and at junctions. The findings described make it possible both to work out the requirements that have to be met by future systems for preventing cyclist-car accidents and to design effective test procedures.

PAPERNO.15-0366-W

Improvement of the Protection of Lower Extremities of Vulnerable Road Users in the Event of a Collision with Motor Vehicles

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ABSTRACT
Since the beginning of the testing activities related to passive pedestrian safety, the width of the test area being assessed regarding its protection level for the lower extremities of vulnerable road users has been determined by geometrical measurements at the outer contour of the vehicle. During the past years, the trend of a decreased width of the lower extremity test and assessment area realized by special features of the outer vehicle frontend design could be observed. This study discusses different possibilities for counteracting this development and thus finding a robust definition for this area including all structures with high injury risk for the lower extremities of vulnerable road users in the event of a collision with a motor vehicle.

While Euro NCAP is addressing the described problem by defining a test area under consideration of the stiff structures underneath the bumper fascia, a detailed study was carried out on behalf of the European Commission, aiming at a robust, worldwide harmonized definition of the bumper test area for legislation, taking into account the specific requirements of different certification procedures of the contracting parties of the UN/ECE agreements from 1958 and 1998.

This paper details the work undertaken by BASt, also serving as a contribution to the TF-BTA of the UN/ECE GRSP, towards a harmonized test area in order to better protect the lower extremities of vulnerable road users. The German In-Depth Accident Database GIDAS is studied with respect to the potential benefit of a revised test area. Several practical options are discussed and applied to actual vehicles, investigating the differences and possible effects. Tests are carried out and the results studied in detail. Finally, a proposal for a feasible definition is given and a suggestion is made for solving possible open issues at angled surfaces due to rotation of the impactor.

The study shows that, in principle, there is a need for the entire vehicle width being assessed with regard to the protection potential for lower extremities of vulnerable road users. It gives evidence on the necessity for a robust definition of the lower extremity test area including stiff and thus injurious structures at the vehicle frontend, especially underneath the bumper fascia.

The legal definition of the lower extremity test area will shortly be almost harmonized with the robust Euro NCAP requirements, as already endorsed by GRSP, taking into account injurious structures and thus contributing to the enhanced protection of vulnerable road users.
After finalization of the development of a torso mass for the flexible pedestrian legform impactor (FlexPLI) it is recommended to consider again the additional benefit of assessing the entire vehicle width.

PAPER NO. 15-0416-W

Finite Element Study of Effectiveness of Modified Front-End Structure with Aluminium Foam in Reducing Pedestrian Injury

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ABSTRACT
Pedestrians are vulnerable road users. Unlike Occupant in cars, they do not have protection equipment and are often involved in serious accidents leading to fatalities. The reduction of pedestrian injuries has recently become one of the most important road traffic accident priorities. For the bonnet type of vehicle, leg and head injuries are the most prevalent type of injury associated with car-to-pedestrian collision. The possible reduction of leg and head injuries can

be done through the design of vehicle bumper structure. Strong and stiff front structure of vehicle usually leads to severe injury to pedestrians in the accident. The use of new class of material like aluminium foam as part of bumper structure can provide better energy absorption capability and hence reduction of impact force to pedestrians. However, in order to design or modify the front structure to be safer for pedestrians, it is necessary to understand kinematics and injury mechanisms of car-pedestrian collisions, which are usually analyzed through costly full scale crash tests of a dummy or a cadaver. Finite element simulations with a human body model are an alternative mean, which offers information of post-crash kinematics and injury mechanisms. This paper has therefore employed the finite element model of pedestrian-city car collisions to study the effectiveness of the modified front-end bumper with aluminium foam in reducing the level of pedestrian injuries. The front bumper structure has preliminary been modified to include the aluminium foam as part of energy absorber. Two relative densities of aluminium foam were selected. The lower density one gave a better injury reduction performance. It was used to simulate a crash with THUMS to study detail injuries of pedestrian. The modified bumper model showed improved performance of injury reduction. The results exhibited the potential use of low density Al-foam in minimizing pedestrian injury and the benefit of using the human body finite element model which provides detailed injury information to help in the design and development of vehicle for pedestrian safety with cheaper cost compared to the actual full-scale crash tests.

PAPERNO.15-0421-W

An inverse Monte-Carlo Based Method to Estimate Pre-Crash Distribution for VRU Safety

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ABSTRACT

Current safety standards are based on maximum stiffness measures over a grid on the frontal surface of a vehicle. The safety of VRU is also influenced by the overall shape of the impacting vehicle. “Initial conditions” [IC] from the dominant crash scenarios are used for CAE simulations in Industrial practice to tweak designs. The IC’s to design for are decided based on cluster analysis from reconstructions of crash data.

Currently, CAE methods to predict the outcomes (final resting state of interacting elements) of a crash deterministically, given the initial conditions are available. But there are no established methods to do the inverse process, that is ascertain the conditions at the initiation of the crash given the final static state of the interacting elements. Recorded data being the final resting state of the interacting elements, the inverse problem is of significance, and is usually tackled by heuristics and iterations augmenting physical laws. While reconstructions of specific cases require detailed observation and experienced personnel, it is hypothesized that estimating a distribution of the pre-impact measures in crashes is more robust with respect to a distribution of the post impact observation than that of individual crashes.

Individual cases from crash reconstruction, approximated to a Gaussian “normal” probability density function, were assumed for the probability of occurrence of individual cases. Crash physics was captured using a multibody simulation in MADYMO solver. An inverse Monte Carlo [MC] simulation with MADYMO solver as the system under study was modelled in “FME” module in statistical software “R”.

A set of post-crash data on head hit location [O1] was generated using forward MC simulation. The variable parameters were four different vehicle profiles, relative position of 50M along vehicle lateral axis [I2] and the relative orientation of with respect to vehicle. The pedestrian represented using one 50th percentile male [50M] pedestrian model was not varied.

Starting with the distribution of “O1” and an “I2” distribution perturbed by up to 20% in mean value as input, an I2 was computed using inverse MC. The “I2” distribution from inverse MC showed less than 10% deviation from the original v3 data set mean with randomized values of untracked variables.

During the inverse MC process, the quality of “fit” to a desired O1 distribution was tracked using the sum of root mean square of differences between normalized density coefficients and a “relaxation parameter” computed as squared logarithmic probability to a normal distribution. The stabilization of the tracking parameter indicated a robust solution.

PAPERNO.15-0433-W

Improvements to the Flexible Pedestrian Legform Impactor: The Development of New Bone Cores

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ABSTRACT

During the first decade of the 21st century, pedestrian safety in general was one of the main subjects of vehicle safety development. For the legform testing, the impactor developed by the European Enhanced Vehicle-Safety Committee was the standard impactor but experts from Japan introduced a new impactor, the so-called Flexible Pedestrian Legform Impactor (FlexPLI). The FlexPLI is capable to quantify the load of a human long bone, which is a significant advantage when developing vehicles with reduced bone fracture risk.

With the impactor being developed by a single company, spare part availability was limited. In addition, potential improvement in terms of robustness in maximum load was identified. Therefore, a joint project was initiated, in which automobile manufacturers and their partners developed universal spare parts for the FlexPLI bone cores. These parts can withstand higher bending loads, are available from stock and do not need to be adapted to a specific legform. Furthermore, a reduction in variation of properties due to a different production process was achieved. This reduces performance variation within the legs and is comparable to the initial bone core mean performance. The document introduces the details of the project.

Testing and Modeling of Structural Performance in Frontal Crashes

Chairperson: Younghan Youn, Republic of Korea; Stephen Summers, United States

PAPERNO.15-0033-W

Study on the Safety Performance of the Rear Safety Guard with Air Bag for Truck

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ABSTRACT

Although the Korea government promotes the movement of safe traffic to reduce deaths in traffic accidents, the number increases every year.

Especially more and more accidents and casualties are reported from the cases of car collision to the back of the vehicles parked for managing car accident on road, cleaning of main roads, side roads and medial strip, and road repair.

Therefore, it has been along that the government should be responsible for taking a protective measure for road users.

71 cases have been reported to occur during highway repair and maintenance. As the result, 8 were dead and 76 were injured, showing the death rate of 11.3%, which is quite high.

So it seems urgent to take some action against it.

America and European countries legislate that vehicles of road repair and maintenance should be mandatorily equipped with shock absorber on car but our country lacks in a legislative measure, which is asked to be done.

Accordingly, this study compares the performance standards of shock absorber for road maintenance vehicle by applying country to establish the criteria.

In addition, it tries to interpret in theory the Rear Safety Guard using Air Bag and compare the safety performance test of a vehicle with the Rear Safety Guard manufactured in accordance with related laws and that using Air Bag.

Based on the result of the safety performance on the 60km/h Rear collision Test, this study proposes improvement in related regulations and laws in an attempt to reduce collision and death by proposing the Traffic Injury Prevention effect of the Rear Safety Guard using Air Bag.

PAPERNO.15-0096-W

Critical Review of the Current Assessment Approaches for Frontal Crash Compatibility Regarding the Evaluation of Structural Interaction

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ABSTRACT

The assessment of structural interaction has been identified as the main challenge of the unresolved problem of frontal crash compatibility. With this background, two questions are raised: Does a better structural interaction correspond with higher safety and crash compatibility? Are current test approaches able to evaluate structural properties?

Considering the structural mechanics of collisions, it is hypothesized that a poor structural interaction does not necessarily result in lower safety and should be considered together with compartment strength and restraint systems. This hypothesis is confirmed by reviewing some crash results from other studies. A spring-mass vehicle model is also used to verify the hypothesis. Finally, a comprehensive simulation study is conducted to find the answers to the two questions. For this study three different variations of a vehicle model are created, which represent different structural properties of the passenger car fleet. The crash performance of these models is analyzed in different car-to-car and car-to-barrier tests.

Results of the car-to-car tests show that better structural interaction often makes the vehicle more aggressive. Generally, better structural interaction increases crash pulse and reduces intrusions. Depending on vehicle design and crash configuration, the intrusions or the crash pulse become more important as to why good or poor structural interaction cannot be overall related to more crash compatibility or occupant safety.
Our criticism of the current assessment approaches for frontal crash compatibility is the establishment of a direct link between good structural interaction and higher safety. These approaches do not consider the effect of higher crash pulses due to the better structural interaction. Our recommendation is to assess the partner protection through metrics about intrusions and crash pulse of the partner, without direct assessment of the structural interaction. Instead, the test configuration should be able to reflect structural properties in intrusions or crash pulse.
Results of the car-to-barrier tests show that the Progressive Deformable Barrier can reflect structural issues correctly. However, the developed metrics for this barrier result in incomprehensive interpretations. Results of the tests with other barriers are inconsistent with the structural properties of the vehicles.
Finally, an exemplary test concept with the Advanced European Mobile Deformable Barrier is presented as an alternative assessment approach. Simulation results of the proposed assessment approach show good consistency with the crash performance of the vehicles in the car-to-car tests. Combination of this test concept with the Full-Width Rigid Barrier test can be used to assess the safety and crash compatibility of passenger cars.

PAPERNO.15-0161-W

A Model of Vehicle-Fixed Barrier Frontal Crash and its Application in the Estimation of Crash Kinematics

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ABSTRACT

The study of vehicle crash process is of great importance in transportation safety. The crash pulses of vehicles during the fixed barrier impacts can reflect the crashworthiness of the vehicle structure. In this paper, a mathematical model of vehicle kinematics during the frontal crash is investigated. This work is based on the analysis of crash response signals and vehicle structure. The proposed model uses piecewise linear functions to describe the trend of crash impulse and ignores the residual oscillations. To study the model variance, the crashes in various speeds and a full car crash in complex condition are compared. At the end of paper, the crash performance of a vehicle crash is predicted according to the proposed model and therefore demonstrates its effectiveness and usability.

PAPERNO.15-0261-W

Consideration of Representativeness of Real-World Accidents and Repeatability of New NHTSA Oblique Offset Frontal Impact Test

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ABSTRACT

The National Highway Traffic Safety Administration has been considering introducing an oblique frontal offset impact test (oblique test) as a new crash test procedure. By means of accident data analysis, it was examined whether this oblique test can represent real-world accidents. Tests were also conducted using two identical vehicles to examine the repeatability of the oblique test. Representativeness of real-world accidents was examined by using the National Automotive Sampling System Crash Worthiness Data System (NASS-CDS) to investigate frontal impact accidents from 2004 to 2008. Repeatability of the oblique test was investigated by conducting the same crash test twice using a midsize sedan. In terms of percentage of the total number of real-world accidents, the most frequent accident modes observed were Full-engagement and Offset frontal impacts, accounting for about 30%. Accidents similar to the oblique test accounted for about 10%. In terms of representativeness of severe injuries, the percentage of brain rotational injuries and lower extremity injuries differed from real-world accident statistics. Brain rotational injuries were considerably different from real-world accidents. With regard to repeatability, vehicle deceleration (G) was almost the same.

However, the degree of cabin deformation differed because of a difference in the buckling mode of the front longitudinal member. Another notable point in the oblique test is that, as the test vehicle weight increases, the Delta-V decreases. However, this tendency is not observed in real-world accidents. To ensure the validity and significance of introducing this test procedure, more test data are required along with continued evaluation and analysis of occupant protection performance based on actual test results.

PAPERNO.15-0282-W

Preliminary Study of the Responses of Hybrid III 5th female, 50th male, Q6 and Hybrid III 5th Pregnant Female Dummy Seated in the 2nd Row Seats of Passenger Vehicles in Sled Tests

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ABSTRACT

The objective of this study was a preliminary study of the responses of dummies seated in the 2nd row seat of passenger vehicles in frontal crashes using a sled system. Q6, Hybrid III 5th female, Hybrid III 5th pregnant female, and Hybrid III 50th male ATD were used in the tests. 8-tests were carried out according to a draft protocol for the 2nd row seat evaluation program. The vehicle type was a sedan and SUV's. The cut-body or jig was used to simulate the ATD in the 2nd row seat/belts of a passenger vehicle. The frontal crash pulse in sled tests was an average acceleration of about 30 vehicle acceleration pulses tested according the KNCAP FFRB test. ATD seating positions were set using the H-point machine. Injury criteria were considered among the HIC15, upper neck tension force, chest deflection. The HIC15 ranged from 350 to 800 for both a Hybrid III 5th female and a pregnant female. The upper neck tension forces of a 5th female dummy and a 5th pregnant female dummy were also higher than that in FMVSS 208. The kinematics was influenced by the seat and seatbelt characteristics. The sled test results were compared with those of the same vehicle KNCAP FFRB test results. The possibility of fatal injury of Hybrid III 5% female and 50% male ATD in the rear seat could have much higher than in the front seat, especially case of the chest deflection. In addition, the further consideration should be given regarding Y- axis in the regulation at the seat belt anchorage point.

PAPERNO.15-0320-W

The Trolley Test Way of IIHS Small Overlap and Side Test

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ABSTRACT

To develop a vehicle in low cost and early well-customized performance trolley test can be used efficiently. In this research, we will introduce how to make the trolley for the IIHS smalloverlap and side crash with substituting parts by CAE validation and show the good validation with real vehicle crash after the test.

PAPERNO.15-0389-W

MOPDB- Mobile Offset Progressive Deformable Barrier: A New Approach to Cover Compatibility and Offset Testing

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ABSTRACT

For more than 25 years the German Automobile Club ADAC is conducting tests to show the consumers and Industry the compatibility of passenger cars. With the upcoming off road vehicles in the 90´s, the structural and mass difference between the compact and the small executive cars according the Off Roaders was huge. The geometries in the vehicle front structures were totally different and did not align in case of a frontal impact. In combination with less performing structures for offset crashes the outcome in a car to car offset frontal impact tests was dramatically worse. Not only the smaller and lighter car showed poor performance also the crash structure of the large off roader failed. A decade later the passenger cars have become much safer due to consumer test programs and regulatory demands. But still these cars are showing a different behaviour in a car to car impact than in a car to barrier impact.

The different results of ODB tests, car to car impacts and the accident analyse showed that there is a need to find a test solution which will show this performance in a full size crash and allow analysing and rating the result.

Several tests with vehicles, barriers and different test conditions have been carried out to find a solution to reproduce real life behaviour and a possibility to rate the vehicle according its aggressiveness and compatibility, which lead to a mobile barrier solution with a progressive deformable element.

Crash Avoidance #1: Safety Performance and Effectiveness of Driver Assistance Technologies, Test & Evaluation Procedures, Benefits Assessment

Chairperson: Bernie Frost, United Kingdom; Anders Lie, Sweden

PAPER NO. 15-0071-W

How is AstaZero Designed and Equipped for Active Safety Testing?

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ABSTRACT

The Swedish test track AstaZero (Active Safety Test Area) is an open environment where vehicle OEMs, tier one suppliers, research institutes, and universities can come to perform development and research. AstaZero is located just outside the city of Borås in West Sweden and was inaugurated in August 2014. The initiative was taken to create an environment for innovation, testing, and research to develop new active safety functions for road vehicles. The four main environments of the facility are built especially for research and development of active safety functions. A city area for simulation of urban traffic, a multilane road, a 5.7 km long rural road, and an innovative high-speed area facilitate efficient testing. Equipment of different kinds is also at hand; test targets, position measurement and control systems, communication equipment, and driving simulators can be provided. However, the success of the AstaZero test bed is also depending on the existence of leading competence. The Swedish automotive cluster has the ability to perform research, industrial development, and rational production of road vehicles. It is essential for AstaZero to have access to strong competence in its vicinity. The organizations residing in the Gothenburg region can be reached in an hour by car. The Stockholm region is more distant but it is quite possible to travel by road in four hours. The success of AstaZero is built on the track, the competence, and all the partners supporting the facility.

PAPER NO. 15-0125-W

Virtual Experimental Environment Design of Camera-Sensor-Based Lane Detection System

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ABSTRACT

Based on the application of software model building, virtual experiment can be conducted with vehicle model, road environment model and sensor model building to develop camera-sensor-based lane detection system in PreScan. These three types of models are connected and the virtual experimental environment is built. Sensor-extracted data are processed by Matlab/Simulink to acquire the accurate ground truth. Meanwhile, images from camera sensor are processed with standard size for further application. The virtual experimental environment design is the foundation for the analysis and comparison of ground true and camera-detected data, as well as for accuracy evaluation in system pre-development. In conclusion, the virtual experimental environment design can be used in camera-sensor-based lane detection system development and is a supplement to traditional system development.

PAPERNO.15-0227-W

Determination of Pedestrian of Mannequin Clothing for the Evaluation of Image Recognition Performance of Pedestrian Pre-Collision Systems

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ABSTRACT

Pedestrian Pre-Collision Systems (PPCS) for helping avoid or mitigate pedestrian crashes have been equipped on many vehicles [1]. At present, there is no common standard for the performance evaluation of PPCSs. The Transportation Active Safety Institute (TASI) at Indiana University-Purdue University-Indianapolis with support from Toyota's Collaborative Safety Research Center (CSRC) has been studying the various issues to support the effort of developing such a standard. An important component in the PPCS evaluation is the development of a standard mannequin. This paper describes the approaches used to determine the color of the clothing on the mannequins based on the data obtained from the TASI 110 car one year naturalistic driving data collected in the greater Indianapolis area in USA.

PAPERNO.15-0245-W

Analysis of Car Accidents Caused due to Unintentional Run Off Road

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ABSTRACT

Car accidents caused by unintentional run off road (in this paper the term "inadvertent lane departure" is used) have become an important topic within worldwide accident research activities. These accidents can be addressed by lateral support systems (e.g. Lane Departure Warning) which are considered by experts to be the second most important active safety countermeasures after forward collision intervention systems.

There is no common understanding for "run off road" yet. This term is being used both for the event of a departure from the own driving lane and for the event of a departure from the road. But it is known that when a driver leaves its driving lane unintentionally, it mostly results in a severe crash involving an oncoming vehicle or an obstacle (e.g. tree).

The importance of this topic is also visible as efforts have already been made in order to adopt this issue in current and future testing procedures (eg. NHTSA, IIHS, Euro NCAP).

In Germany, the relevance of unintentional run off road accidents can hardly be estimated when using only official numbers. Official statistics categorize accidents by the parameter "leaving the carriageway" without any differentiation between intentional or unintentional lane departure. However, in the year 2013, these accidents made up 14% of all accidents with personal injury involving all kinds of road users but 30% of all fatalities and 23% seriously injured persons. A more accurate view on the accidents that match the definition "unintentional run off road" was given by UDV in an earlier study (paper-09-0317).

This paper presents now the results of a second more detailed analysis which was carried out with up-to-date accident data. For the analysis, the In-depth database of the German Insurers (UDB) was used. It contains a representative cross section of all third party insurance claims reported between 2002 and 2011. The group of car accidents analyzed was defined as "unintentional run off road accidents" and implies only cases where a car had left his driving lane

unintentionally. The aim of the analysis was to get a better understanding of the circumstances at which these incidents occur and to derive key accident scenarios.
From a total of 118 relevant cases in the database, which account for 5% of all accidents caused by a car, five accident scenarios were deduced. These make up 68% of the accidents and 66% of the fatalities in the datapool. Some of the main results were: A lane departure to the left occurred more frequently than a lane departure to the right. Generally, the lane departure was followed by a collision with an oncoming vehicle (in 70% passenger car) rather than by a run off from the road. Regarding behavioral issues, health problems of the driver were found to be twice as frequent as distractions of any kind.

PAPERNO.15-0256-W

Evaluation of Motorcycle Antilock Braking Systems

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ABSTRACT

Objective: Previous studies have found lower crash rates for motorcycles equipped with antilock braking systems (ABS). Although prior studies controlled for a variety of personal factors related to motorcycle crashes, they did not control for the possibility that riders with similar demographics still can differ in the likelihood that they buy optional safety equipment and that this difference might be related to their crash likelihood. Specifically, motorcyclists who purchase ABS might be more likely to behave in a manner that makes them less likely to crash. The purpose of the current analysis was to examine the influence of individual crash risk on the frequency of insurance claims under collision coverage for ABS-equipped motorcycles. Auto collision claim histories were used as a proxy for the crash risk of individual riders, independent of the motorcycles they ride.

Methods: Coverage and loss data on nearly 2 million motorcycles by their unique vehicle identification numbers (VIN) were supplied by 13 insurers for model years 2003-14. The VINs were used to determine the ABS status of each motorcycle. Demographic characteristics including gender, marital status, date of birth, zip code, and insurance company were used to match the riders of these motorcycles to their auto insurance histories. Riders without any auto insurance history were excluded. Regression analysis was used to quantify the effect of ABS while controlling for auto claim frequency and other covariates including rider age and gender, garaging state, and collision deductible.

Results: Motorcycle riders with higher auto collision claim frequencies were associated with higher motorcycle collision claim frequencies. Riders with high auto claim frequencies (an average of more than two auto claims per 5 years insured) were associated with motorcycle claim frequencies that were 64 percent higher than those for riders with a history of zero auto claims. The percentage of motorcycles with ABS optionally equipped increased with the riders' auto claim frequencies. After controlling for auto claim frequency, motorcycles equipped with optional ABS were associated with a 21 percent reduction in claim frequency compared with similar motorcycles without ABS. Further analysis indicated that the reduction in motorcycle claim frequency associated with motorcycles equipped with ABS did not vary significantly depending on the auto claim frequency of the rider.

Discussion: Among motorcyclists with both auto and motorcycle collision insurance coverage, there was a strong relationship between motorcycle and auto claims experience. However, there was no evidence that safer riders, as measured by auto claim frequency, were more likely to purchase motorcycles with optional ABS. Rather, riders with higher auto claim frequencies were more likely to ride motorcycles with ABS. Most important, controlling for a rider's auto claim frequency did not substantively change the observed ABS effect, and the 21 percent estimated reduction in motorcycle collision claim frequency was consistent with prior research.

Conclusion: This analysis evaluated the real-world safety benefits of motorcycle ABS while also addressing the potential influence of self-selection by safer riders. Results indicate that all riders may be expected to benefit from ABS technology on their motorcycles. This study also confirms that auto crash risk is a reasonable proxy for a safety profile that may be applied to future research on other optional safety technologies.

PAPERNO.15-0341-W

Limitations of Use of an Inertial Positioning System in a Truck during a Maneuver of Avoiding a Suddenly Appearing Obstacle

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ABSTRACT
The objective of this work is to find limitations of using MEMS-type accelerometers and gyroscopes for finding position of a vehicle in short time prospective (few seconds). Such a system could be helpful for automated vehicle driving in some situations, like bypassing a suddenly appearing obstacle. A Monte-Carlo analysis was performed to find introduced position and direction errors for various trajectories of the vehicle. Transducer noise, offset and calibration errors were taken into account as possible error sources. Also, the influence of limited data sampling rate was checked. The results are presented in form of difference statistics between real and calculated vehicle position and orientation at the end of the track as function of various parameters, including the trajectory and performance of the used sensors. The Monte-Carlo simulation accuracy was checked by bootstrap method and the errors were shown in resulting plots. Presented results show that an inertial system can be used for determining the vehicle's position with accuracy reaching centimeters. Also, it is shown that compensation of the sensor offsets, as well as knowing the initial conditions are critical for the quality of the track reconstruction.

PAPERNO.15-0348-W

Parking Crashes: The Rationale for Action and the Development of Test Procedures

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ABSTRACT
Studies of UK insurance claims data suggested that approximately 23% of all crash claims (by value) arose from incidents that could be classified as parking crashes, collectively accounting for a claims value approaching £2billion per year. Advanced technology has proven capable of preventing higher speed crashes that might nominally be considered more challenging than crashes involving low speed maneuvering. So, it was considered that research was required to investigate these crashes in more detail to identify their common characteristics, whether the patterns were replicated elsewhere in the world, what scope there would be for crash avoidance technology to be used to prevent them and, if so, what test procedures would be required to allow fitment of the most effective systems to be incentivised.

International analyses undertaken by the RCAR network of insurance research centres found evidence suggesting that parking crashes typically made up between approximately 15% and 25% of claims value around the world. The data showed that these claims most frequently involved reversing and collisions with another vehicle (mostly in combination with reversing). Collisions with vulnerable road users made up a small proportion of claims but often involved children or the elderly with very serious outcomes.

The technology required to prevent low speed reversing collisions with other vehicles, posts and vulnerable road users already exists. Several models of Infiniti, Mazda and Cadillac are already equipped with parking crash avoidance systems

and several other models are available with park assist systems. The latter incorporate some similar functionality but only when the assisted parking is selected by the driver.

A comprehensive parking test programme was defined to assess the potential of systems. This involved collisions with different obstacles (car, post, pedestrian) in both parallel and perpendicular parking scenarios, considering a wide range of variables including different impact positions or vehicle overlaps, varying approach speeds, and straight or curved approaches at different speeds and steer angles.

The results showed that while the performance of different systems varied, excellent potential existed to avoid a large proportion of low speed maneuvering crashes. Predicting the exact extent of the likely effects is limited by inconsistencies in the way parking crashes are recorded in different countries and the results are based on the performance of only a small number of vehicles because few are yet equipped with the relevant technology.

However, overall the work undertaken shows that there is a huge cost associated with parking crashes and that technologies exist that have excellent potential to substantially reduce the costs and that this potential can be readily tested and assessed. There is, therefore, a very convincing rationale to incentivise further development and wider fitment of such systems. It is proposed that the test procedures developed so far are refined and rationalised and then incorporated within a suitable incentive scheme, such as Insurance Group Rating and/or New Car Assessment Programmes around the world.

PAPERNO.15-0351-W

Technologies for the Prevention of Run-Off Road and Head On Crashes

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ABSTRACT

Analysis of UK insurance claims suggests that approximately 20% of claims involve “head-on” or “single vehicle” collisions. These can occur as a result of a misjudged action (e.g. overtaking), loss of control (e.g. skidding on poor surface) or inattention (e.g. distraction or impairment). Lane Departure Warnings are widely fitted and were intended to reduce the incidence of collisions caused by inattention. However, research in the US (IIHS, 2012) suggests that LDW has not reduced claims in the way other ADAS technologies have. Lane Keep Assist is a further development that acts not only to warn the driver but to actively steer the vehicle back into its lane. The evidence from the development of FCW and AEB, where the automated intervention produced approximately double claims reduction of only the warning, suggests that LKA might have the potential to be more effective than LDW. Each of these systems can offer a certain degree of intrusion on normal driving, particularly on narrower two way highways with curves. Mercedes have taken the concept further than other manufacturers in a system that could be categorised more as an Autonomous Emergency Steer (AES). Their system will not necessarily intervene to correct a lane departure unless an oncoming or overtaking collision threat is detected. However, if an imminent threat is detected then the ESC can be used to adjust the vehicle heading via differential braking and avoid the collision more effectively than standard lane keep assist. So it has the potential to reduce intrusion into normal driving, boost driver acceptance, and improve effectiveness in dangerous situations. The objective of this research is to examine real world collision data in detail to better understand the potential effectiveness of lane keeping technology and explore the capabilities of different technologies.

Lane departure crashes are relatively evenly distributed between straight and curved roads and between lane departures to the left and right. A relatively small proportion involves collisions with other vehicles but these tend to be some of the most serious crashes. In around 90% of cases, lane markings were present and in most cases the markings were in good condition. Collisions are typically characterised by relatively high speeds combined with some form of inattention, e.g. distraction, drowsiness or impairment.

The analyses suggests that there should be significant scope for lane assist systems to be of benefit and supports the theory that systems that intervene may be more effective than warning. However, the large data sources required for statistically significant analyses do not tend to include sufficient technical detail to allow analyses focused on the specific collision type and this continues to limit the ability to measure claims effectiveness.

The analyses suggest that crash avoidance technologies aiming to avoid run-off road and head on collisions based on Autonomous Emergency Steering should prove to be an effective casualty reduction measure. It also provides substantial characteristic data that will be used to inform the development of a representative test procedure allowing fitment and optimisation of systems to be incentivised.

PAPERNO.15-0355-W

The Development of Assessment Technologies for Advanced Safety Vehicles

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ABSTRACT

Like many industrialized countries, the Republic of Korea (ROK) has implemented policy and research aimed at reducing the number of casualties caused by traffic accidents. For example, ROK launched the project titled "Reduce traffic casualties by half in 10 years" in 2008, Sweden introduced the Vision Zero Policy in the late 1990s, and other European Union members have launched similar projects aimed at reducing traffic accident fatalities by between 30 to 50 percent.
To reduce the number of casualties from road accidents requires improvements to vehicles, road and traffic managements systems. To expedite this process Intelligent Transport System has been adapted and implemented to the vehicles and road systems.
Vehicles with advanced safety features will be expected to reduce or prevent accidents which drivers cannot not respond to or perceive.
To date, there has been insignificant research into the effective performance of vehicles with advanced safety features. The lack of assessment procedures has impeded the public acceptance of vehicles with advanced safety features.
The Development of Assessment Technologies for Advanced Safety Vehicles has been introduced for the promotion of advanced safety vehicles. The project involves the development of assessment technologies for advanced safety vehicles.
This paper shows the development of assessment methods for passive and active safety technologies. These technologies primarily address active protection for pedestrians, rear passenger safety, lane keeping assistance system, and automatic emergency braking system.

PAPERNO.15-0395-W

Safety assessment procedure for Advanced Emergency Braking System

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ABSTRACT

This paper suggests a safety assessment procedure for evaluation of enhanced longitudinal safety by Advanced Emergency Braking (AEB) system in Korea. The objective of project is to suggest safety evaluation procedure of the AEB system with the consideration of Korean road condition and physically meaningful situation.

To develop the impact assessment procedure of the AEB system, the AEB test vehicle as well as the test scenario should be designed. Before the development of the test procedure, this paper reviews the international regulation of AEB system and traffic accident statistics, and develops domestic safety standards and evaluation requirements. Test scenario has been developed to assess the safety performance of AEB systems for the reductions in collision frequency and severity by using the Koreaį¯s traffic accident statistics. Also, the test scenario is designed to represent the real driving condition and to evaluate the safety performance of AEB system in various situations. The AEB test vehicle comprises of a millimeter wave radar sensor, CCD camera and pre-developed AEB algorithm of which are processed to judge the collision risk. To evaluate the collision avoidance performance of the AEB test vehicle, pre-performance test was conducted by using the NCAP-AEBS draft test procedure and proposed test scenario.

From the traffic accident statistics and the field test result, it is shown that proposed AEBS test scenario represents not only the frequently occurred collision case but also physically meaningful situation in terms of expected control performance of the AEB system. Also, it has been shown that AEB system of prior study can reduce the collision velocity and provide the greatest real world benefits. Because of the limitation of test equipment and safety, test scenario about Cut-in vehicle could not be included in the test results of the proposed test procedure. However, by using the analysis methods and simulation test, the safety effect for enhanced longitudinal safety of the AEBS with respect to Cut-in case has been assessed scientifically.

In this paper, the safety assessment procedure for AEB system has been described to evaluate the safety performance of the AEB system. The test procedure according to AEB system provides objective safety performance level of each AEB system. Also, these tests are expected to be a strong driver of improved safety in the real world.

Biomechanics #1: Development, Validation and Use of Human Body Models in Assessment of Crash Injury

Chairperson: Matthew Craig, United States; Rainer Hoffmann, Germany

PAPERNO.15-0429-W

Correlation between THOR BrIC and TBI Risk from Full Body Human Model

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ABSTRACT

The Brain Injury Criteria (BrIC) was recently developed by using two human head models (SIMon and GHBMC) and ATD impact and crash test data. This study used a system simulation approach to further investigate correlations between BrIC from the THOR sled tests in the NHTSA Advanced Adaptive Restraint Program (AARP) and the human occupant traumatic brain injury (TBI) AIS 4+ risks estimated with a full body human model.

Eleven sled tests for the 50thpercentile male THOR Mod Kit dummy performed in AARP were selected as the basis for this analysis. The measured THOR BrIC values from these tests ranged from 0.49 to 1.89. For each of the THOR sled tests, a FE system model was built and the correlation was confirmed with the physical test data. The full body human model, a combination of the GHBMC head model and the in-house Takata human body model (TKHM), has been validated at component and full body levels. The THOR dummy model was then replaced with the full body human model in the system and the sled test simulations for the human under the same test conditions were conducted. The maximum principal strain (MPS) and the cumulative strain damage measure (CSDM) from the human head model were calculated from deformation of the brain tissue elements. The risks of AIS 4+ TBI injuries per the CSDM and MPS measures were compared with those estimated with BrIC from the THOR sled tests using paired student t-tests.

Overall, good agreement of the head, chest and pelvis translational accelerations and the head rotational velocities between the THOR dummy and the human body model were found for the full frontal sled cases. Differences between the two were observed for the head rotational velocities under the oblique sled test conditions. The results of additional simulations where an impactor struck laterally the face-jaw of the THOR, TKHM and GHBMC indicated that the THOR head-neck twisted more and faster than the human models, which could be a major cause of the inconsistency in the oblique cases.

Linear correlations between the THOR BrIC and the AIS 4+ TBI risk estimations from CSDM and MPS outputs of the human model were observed (with R2 score of 0.81 for CSDM and R2=0.85 for MPS). The TBI risks estimated from the THOR sled tests and the human model were similar in the full frontal, while the BrIC from the THOR sled tests overestimated the TBI risks.

Testing and Modeling of Structural Performance in Side Impact and Rollover Crashes

Chairperson: Bengt Pipkorn, Sweden; Mark Terrell, Australia

PAPERNO.15-0016-W

Characteristic Analysis of Passenger Cars' Side Impact Based on In-Depth Accident Research in China

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ABSTRACT
Based on the in-depth accident study of 138 cases occurred in Shanghai, China, in which a passenger car got side impact, the characteristics of human - vehicle/equipment - environment factors were analyzed in order to reveal the causation and damage/casualty consequence of these side impact accidents. The results show that the average deformation of these side struck passenger cars was 22.4cm. Furthermore, the deformations caused by large striking vehicles (trucks and buses) were 52% larger and the ratio of critical casualty consequence (serious injury or death) hovered at 22%. On the other hand, the highest mortality occurred at both sides of rear seats, and was nearly 13%. The head and neck were the most prominent injured parts of the body, which occupied narrowly 64% of the casualties. These above objective characteristics of side impact accidents provide a reliable basis for the development and application of occupant protection system and collision avoidance technology in China.

PAPERNO.15-0107-W

Analysis of the Influence of Motor Cars' Relative Positions during a Right-Angle Crash on the Dynamic Loads Acting on Car Occupants and the Resulting Injuries

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ABSTRACT
Side collisions of vehicles participating in the traffic are very common road accidents in Poland. In 2013, such collisions amounted to 29% of all the traffic accidents and they were accountable for 31% of the injured and 18% of the killed among all the accident victims. In spite of a decline in the total numbers of road accidents and of the resulting casualties, recorded for more than the recent decade, the percentages of side collisions of vehicles in the traffic and of the resulting casualties in the total figures have been observed to grow. On the other hand, the severity rate of accidents of this type has been remaining for many years on a stable level while it has been decreasing for other vehicle crash types. This shows that the progress in the protection of motor car users from the effects of side impacts is too slow. Therefore, it seems reasonable to carry out research on the processes that take place during side collisions.
A research project, expected to facilitate the exploration of the course of some processes in result of which dynamic effects are produced by a right-angle collision of two motor cars on car occupants, has now been in progress at the Automotive Industry Institute (PIMOT) in Warsaw. Within the project, six crash tests were performed with the use of 12 passenger cars of the same make and model. At each test, the front of car A crashed into the left side of car B. The pre-

impact speed of car A was about 50 km/h and it was twice as high as that of car B. At successive tests, different places on car B were struck by car A. In each car, a Hybrid III test dummy was placed on the front right seat and a Hybrid II dummy was placed on the front left seat.
The measuring systems used made it possible to determine the following:

- dynamic interactions between the cars;
- lateral displacements of the torsos and heads of the dummies placed on the front car seats;
- dynamic loads acting on dummies' heads and torsos;
- relations between the force applied to car B and the dynamic loads acting on the occupants of that car

The paper includes test results, thanks to which the time histories of the force acting on the impacted car as well as the effect of this force on the displacements and accelerations of the test dummies could be presented.
An analysis of the test and computation results has shown that the location of the place of impact on car B has a considerable influence on the loads received by the car occupants. The knowledge of the dynamic loads acting on the occupants of front seats of car B makes it possible to predict the likelihood and scope of injuries to the occupants depending on the relative positions of the car during a collision.
The test and analysis results presented herein will be used for improving the construction of the system of individual protection of motor car occupants, including a system to restrain lateral displacements of car occupants during a side collision.

PAPERNO.15-0153-W

Investigation of the Influence of the Centre of Gravity Position on the Course of Vehicle Rollover

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ABSTRACT

Rollover crashes belong to the most danger type of road accidents. Particularly vehicles with a high situated center of gravity are exposed to this type of accidents. The basic measure of vehicle resistance to rollover is Static Stability Factor SST, i.e. the ratio of half the track width to the height of the center of gravity. In the quasi-static rollover limit it is assumed that the SST should not be less than the tire-to-road friction coefficient. This follows from the assumption that the side skid is less dangerous than the rollover. Most of the passenger cars are designed in order to prevent the rollover on flat surface with normal friction. However from several reports it is known that the quasi-static rollover limit can be not met in the case of vehicles with a high center of gravity position (in relation to the tread): heavy trucks, delivery vans or busses, especially high-floor coaches and double-deckers. Also other cars especially, very trendy at present, SUVs and trucks could also undergo the rolling over when the tire-to-road friction coefficient would be extremely high, namely its value would exceed 1 or more. The rollover can happen on a flat surface also when the height of the centre of gravity is higher than the height assumed by the designers.
In the paper the method of calculation of the course of rollover in time domain is described and it is investigated an influence of the height the centre of gravity on an increase of the rollover angle velocity. The conducted calculations show that during rollover the rotation angle of the vehicle increases progressively. It can be noted that the higher the vehicle centre of gravity is located, the faster the rotation angle increases.
On the basis of calculation results it is discussed whether the drive has a chance to counteract the rollover of the vehicle. It is shown, that in a few first tenth parts of the second the angle of the rotation is small enough that it gives the driver a chance to correct the movement of the car using the steering wheel or by reducing speed, even when the rollover process has already begun.

PAPERNO.15-0444-W

Opportunities for Reducing Far-Side Casualties

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ABSTRACT

This paper uses NASS 2004-2013 to estimate the population of belted front seat occupants exposed to far-side crashes and those with serious injuries. The use of the most recent ten years of NASS data permitted an update of the characteristics of far-side crashes that are associated with serious injuries among belted front seat occupants. When compared with earlier studies, it was found that the vehicle category that includes SUV's, pickups and vans, has increased as the collision partner in far-side crashes. There has likewise been an increase in the median crash severity for MAIS 3+ injured. For the 2004-2013 NASS CDS data, the median crash severity for MAIS 3+ injured was a lateral delta V of 36 kph. Chest/abdominal injuries accounted for 43% and head injuries accounted for 23% of the AIS 3+ injuries. Drivers accounted for 79% of the MAIS 3+ injured belted front outboard occupants that were involved in far-side crashes. About 53% of front outboard occupant's chest injuries were caused by contacts with the vehicle center stack or seat back and 21% were associated with contacts with the far-side structure. In regards to head injuries, the far side structure accounts for more than 60% of the AIS 3+ injuries. Of the far side crash involved occupants analyzed, they sustained AIS3+ head or chest injuries from the far side of the vehicle more than 4.4 times more often than were attributed to occupant to occupant contact. Another striking trend is the disproportionate number of AIS3+ injured occupants in light passenger cars where belted front outboard occupants sustained severe injuries at a rate 2.7 times higher than exposed. Finally, this study identified that only 3.1% of belted AIS3+ injured occupants involved in far-side collisions sustained their injuries due to head to head contact with another front seat occupant.

Biomechanics #2: Advances in Crash Test Dummies, Instrumentation and Data Analysis

Chairperson: Philippe Vezin, France; Yasuhiro Matsui, Japan

PAPER NO. 15-0085-W

Matching Structural Injury Risk Statistics and Dummy Injury Measures for Dynamic Compliance and Ratings Rollover Regulatory Test

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ABSTRACT

A study was conducted on five different vehicles. Each vehicle was dynamically rollover tested using similar rollover test parameters. The study was performed to examine the major factors in a rollover that match structural injury risk to injury measures for occupants that were neither ejected nor partially ejected.

PAPER NO. 15-0325-W

First Generation Obese ATD (FGOA)

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ABSTRACT

This paper sets forth the need for an Obese ATD. The goal of this study was to build a prototype that accurately represents an obese subject with a BMI of 35 kg/m2, and also to explore new ATD flesh material options.

The prototype ATD was designed using a THOR-M platform and a 35 kg/m2 BMI target. The finished prototype was then tested on a rear seat buck at 29 km/h and 48 km/h. The kinematic data from these tests was compared to the kinematic data from previous tests ran at the University of Virginia using a 35 kg/m2 BMI PMHS. This comparison was used to evaluate the existing prototype and reform the next iteration of the ATD.

Crash Avoidance #3: Connected and Automated Vehicles

Chairperson: Tim Johnson, United States; Jonas Sjöberg, Sweden

PAPERNO.15-0430-W

Target Crash Population of Automated Vehicles

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Abstract
This paper describes a method to determine the target crash population that could be addressed by automated vehicles. The method maps specific automated vehicle functions to five layers of crash information including crash location, pre-crash scenario, driving conditions, travel speed, and driver condition. The focus of this paper is on automated vehicle functions at automation levels 2 through 4 as defined by the National Highway Traffic Safety Administration. This paper identifies the automated vehicle functions and their automation levels, operational characteristics and conditions, and applicable pre-crash scenarios through literature review and relevant research programs. This paper also identifies the approach to query the crash data and account for level 0 and level 1 automated vehicle functions when estimating target crash populations for automated vehicle functions at levels 2 through 4. The application of this method, using the General Estimates System and Fatality Analysis Reporting system crash databases, would express the target crash populations in terms of the annual frequency of all crashes, fatal-only crashes, and involved persons at different injury levels.

Advanced Fuels Crash Safety

Chairperson: Jost Gail, Germany; Lars Hoffmann, Sweden

PAPERNO.15-0074-W

Detection of Fires in Heavy Duty (HD) Vehicles

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ABSTRACT

Detection of fires in the engine compartments, toilet compartments, baggage bays and sleeping cabins of Heavy Duty (HD) vehicles is arduous. The elevated air flows, concentration of pollutants and wide range of surface temperatures in the engine compartment together with the complicated geometries of the latter spaces complicate the operation of all types of detectors. These lead to difficulties defining the optimal type of detection technologies to be used as well as the adequate location of each detector.

This paper presents research for understanding the challenges and necessary characteristics of detection systems in compartments with high air flows, large temperature variations and complicated geometries. In particular, this work reports about literature surveys of existing standards, legislations and research in the field as well as experimental findings.

PAPERNO.15-0248-W

High Risk E-Vehicle Battery Sled Testing

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ABSTRACT

Crash testing of E-Vehicles (electrified vehicles, e.g. electric and hybrid electric vehicles) is required to assure compliance with global safety regulations and standards as well as the even higher requirements set by the car manufacturers themselves. The introduction of E-Vehicle battery systems of as much as 200 to 600 Volt dc presents new safety considerations when performing crash tests. At a crash test, safety by regulations, standards and ratings as well as the limits of durability are investigated. If investigating the limits of durability, scenarios such as release of harmful gases and thermal events must not be disregarded. In order to ensure safe testing conditions, regardless of the severity of impact to be evaluated, new risk analysis, routines and laboratory designs need to be assessed when a new technology, such as high voltage (HV) battery systems, are introduced to the vehicle market.

Autoliv has a long experience in crashworthiness testing and offers car manufacturers assessments of crash safety in laboratories and crash tracks available on all continents. E-Vehicles are being crash tested as well, and for that reason Autoliv have established research and testing capabilities for HV batteries as well as updated routines and laboratory designs. Besides Autoliv's full size crash tracks around the world a new laboratory facility for battery sled testing is now available in Sweden for high-risk durability-limit testing.

Consumer Information Approaches To Improve Global Safety Chairperson: Andre Seeck, Germany; David Ward, United Kingdom

PAPERNO.15-0042-W

Improving Vehicle Safety in Australia and New Zealand: The Role of ANCAP

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ABSTRACT

The Australasian New Car Assessment Program (ANCAP) has had a significant impact on the Australian and New Zealand motor vehicle landscape over the past 20 years through its independent, non-regulatory, consumer-driven program. Five star cars are now available in all vehicle categories; the majority of manufacturers now approach ANCAP to obtain a rating prior to launch to leverage sales; and ANCAP assessments are now seen as the de facto standard, taking the place of regulation. Since 2011 ANCAP has been increasing the stringency of its requirements for each star rating level annually. In future years ANCAP will continue to raise the bar, updating and broadening its suite of physical crash tests and introducing performance testing of safety assist technologies (SAT). These advancements will see consumers provided with even safer vehicles, and in time, perhaps even cars that will not be able to crash at all.

NCAPs drive vehicle safety improvements through a non-regulatory approach. This paper examines the effectiveness of the Australasian NCAP, its achievements and its future direction.

PAPERNO.15-0069-W

Consumer Response to Vehicle Safety Ratings

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ABSTRACT

This study assessed how the release of the Insurance Institute for Highway Safety's (IIHS) new crashworthiness ratings based on a small overlap front crash configuration and ratings of front crash prevention systems affected consumer behavior. Telephone surveys were conducted with U.S. Volvo dealers after the August 2012 inaugural release of the IIHS small overlap frontal crash test ratings, in which the Volvo S60 was one of two models receiving the highest rating of good, and with U.S. Subaru and Jeep dealers after the May 2013 release of small overlap frontal test ratings of small SUVs, in which the Subaru Forester was the only model rated good and the Jeep Patriot was rated poor. Additional surveys were conducted following the September 2013 inaugural release of IIHS's front crash prevention ratings with U.S. Subaru, Volvo, and Cadillac dealers, automakers that offered automatic emergency braking systems receiving the top superior rating; U.S. Ford dealers, which offered a forward collision warning system rated basic; and U.S. Hyundai dealers, which had no rated system and offered little collision avoidance technology at the time.

Nearly half of Volvo dealers and 75% of Subaru dealers reported increased consumer interest in the S60 and Forester models, respectively, after their good ratings in the small overlap frontal test were broadcast. Volvo dealers reported a 41% increase in sales of the S60 and an 18% increase in sales of all Volvo models the week following this announcement compared with the week before. Subaru dealers reported a 14% increase in sales of the Forester and an 11% increase in all Subaru models compared with the week before the announcement, while Jeep Patriot sales declined slightly and sales of all Jeep models were essentially unchanged. About a third of Subaru, Volvo, and Cadillac dealers and 10% of Ford dealers reported increased consumer interest in front crash prevention systems after the inaugural ratings were released. Sales for all surveyed automakers declined from the week before the front crash prevention rating announcement to the following week. However, sales of Subaru, Volvo, Cadillac, and Ford models with rated systems declined 41% less than sales of Hyundai models, and sales of all models from these automakers declined 6% less than sales of Hyundai models. The findings suggest that well-publicized safety ratings can translate directly into changes in consumer vehicles purchases.

PAPERNO.15-0144-W

The Australian Terrain Vehicle Assessment Program (ATVAP)

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ABSTRACT

Around 12 to 14 people are killed and 1400 injured annually in Australia resulting from Quad bike (All- Terrain Vehicle - ATV) and Side by Side Vehicle (SSV) incidents. The Australian Terrain Vehicle Assessment Program (ATVAP) consumer safety star rating system has been developed on the basis of a series of tests assessing a vehicle's static stability, dynamic handling and rollover crashworthiness and is being proposed as a method to reduce these serious and fatal injuries mainly resulting from Quad bike rollovers.

The ATVAP objective is to introduce a robust, test based rating system, in order to provide consumer based incentives for informed, safer and appropriate vehicle purchase, highlighting 'Fit For Purpose' criteria, with corresponding incentives and competition amongst the Quad-bike and SSV industry for improved designs and models. This paper presents an overview of the testing basis on which the proposed rating system was developed.

PAPERNO.15-0152-W

A Study on Toughened Glass Used for Vehicles and its Testing Methods

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ABSTRACT

Toughened glass for vehicles is used for most window glass, except for windshield glass, and in particular is also generally used for sunroofs installed on the roofs of vehicles. Toughened glass is known to have external impact resistance that is about four times stronger than original glass.

We would like to verify that ceramic-printed toughened glass does not meet of GTR(Global Technical Regulations) No. 6 and its strength is lower than original glass through tests.

The tests were conducted with the test piece of original glass, toughened glass, and ceramic-printed toughened glass from five glass manufacturers. In Test 1, a 227g steel ball was dropped from a height of 2 meters, and damage was checked according to the test method of GTR No. 6, and in Test 2, a steel ball was freely dropped from different heights and limited damage height was determined.

In the result of Test 1 according to the test method of GTR No. 6, while all five test pieces of toughened glass were not damaged, all the ceramic-printed toughened glass from the five manufacturers were damaged.

In the result of Test 2, none of the five test pieces of toughened glass were damaged by a 10m ball drop, the original glasses were damaged by an average of 3m ball drop, and the ceramic-printed toughened glasses were damaged by an average of 1.4m ball drop.

As the results of the tests show, ceramic-printed toughened glass does not have the features of toughened glass due to its very low strength.

Therefore, we would like to contribute to the safety of consumers by considering the GTR No.6, and by revising the toughened glass test method.

PAPERNO.15-0275-W

The Assessment Results of the Advanced Safety Technology in JNCAP and its Future

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ABSTRACT

The Japanese government has set up the target of fatalities-from-traffic-accidents reduction. Its aim is to be at the safest traffic society in the world. However, the reduction rate of the death toll in Japan has declined but it's still in a severe situation. Moreover, we have a rapidly aging society. This is another problem.

On the other hand, with the rise of a national safety consciousness, many cars equipped with advanced technology are available on Japan's market including the small sized car, so called KEI-car and it is in the most diffused situation in the world at a present stage. But more promotion is desired.

Nevertheless, an understanding about a difference of the performance and the characteristic of that technology are not yet understood efficiently.

Although NCAP has so far achieved big success by the technique of the information dissemination to a consumer for improvement in the safety performance of a car, extending this to the domain of advanced safety technology is called for. JNCAP started advanced safety technology assessment from 2014 based on our roadmap. In 2014, we adjusted the protocol of the procedure of Autonomous Emergency Braking System (AEBS) test, Lane Departure Warning System (LDWS) test and an evaluation method.

In the protocol of an evaluation method, it is prescribed that an official announcement shows the overall points of several results of advanced safety technology assessment.

We are targeting the spread of technology by evaluating various advanced safety technology synthetically and thus more technical development is urged with the digitization technique of evaluating the reduction effect of a deaths and serious injury accidents based on the actual accident data from Japan.

We implemented the assessment according to these protocols and released the result of 37 models in FY2014.

So, various characteristics for every technology became clear as a result of the AEBS tests. Although various technologies, such as laser radar equipment, millimeter-wave radar equipment, mono-eye, dual-eye camera is used, we are able to discuss about the important information we should give to a consumer and the future course of the advanced safety technology depending on current test results.

Finally, I would also like to write about the future work of JNCAP based on the discussion taken in our steering committee meetings and the WGs.

PAPERNO.15-0306-W

Howsafeisyourfirstcar.Com.Au – A Website to Assist Young Drivers to Find a Safe Car, in Their Budget

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ABSTRACT

Young drivers constitute approximately 13% of all license holders, yet they represent around 25% of drivers killed each year. Although gains have been made in reducing the number of young people being killed and seriously injured on our roads, they continue to be overrepresented in fatal and serious injury crashes each year.

Research has demonstrated that young drivers are at greater risk because they are inexperienced and more likely to take risks on the road.

Some of the factors that increase the risks of crashing among young drivers include:

- Driving with peer aged passengers
- Night time driving
- Use of mobile phones

- Drink/drug driving
- Speeding
- Driving older and less safe cars

Research shows that young drivers tend to drive the least safe and oldest cars on our roads. Research from the Monash University Accident Research Centre (2009) demonstrated that:

- Both female and male young crash-involved drivers are driving older vehicles than their older counterparts.
- Young males are driving older vehicles than females.
- Young female drivers are driving smaller vehicles than their older counterparts.
- Crashworthiness of cars driven by younger drivers is poorer than for older drivers.
- Young female's cars are less crashworthy than young male's cars.

An annual survey from the Transport Accident Commission (TAC) demonstrates that 24% of 18-25 year olds intend to buy a new car, 51% intend to purchase a used car and 25% are undecided. Safety features rank second in importance for 18-25 year olds after condition of vehicle (and price). 67% of 18-25 year olds say they will consider crash test results or safety ratings before purchasing a car, compared to 71% of 26-39 year olds, 64% of 40-60 year olds and 87% of 61+ year olds. 23% of 18-25 year olds say they will not consider safety ratings, and 11% don't know.

In addition to other initiatives to improve young driver safety, including a graduated licensing scheme and school based road safety education, the TAC has now developed a website to make it easier for young drivers to find a safe car within their budget. The website allows users to search through a database of cars that have a 4 or 5 star Australasian New Car Assessment Program (ANCAP) rating or Used Car Safety Rating (UCSR) and are approved by the roads authority for probationary license holders to drive. Users can search by price ranges starting from as low as $2,500 to find a safe car, within their budget.

This paper will detail the background research, development of the website, including data used, marketing strategies and an early evaluation.

PAPER NO. 15-0318-W

Crashworthiness Testing Of Electric and Hybrid Vehicles

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ABSTRACT

Electric and hybrid vehicles are increasingly being offered as a means to provide personal transportation with less negative impact on the environment and lower operational cost. While still representing a small portion of fleets in industrialized countries, the availability of these types of vehicles is growing. Electric and hybrid vehicles comprised approximately 1 percent of new vehicle sales in the United States in 2004, and by 2013 this had grown to almost 4 percent. As a result, there is considerable interest in the crash safety of these vehicles and, in particular, potential hazards unique to their electrical drive systems such as electrocution, fire, and electrolyte spillage. This paper summarizes the crash test experience of electric/hybrid vehicle from the Australasian New Car Assessment Program (ANCAP) and Insurance Institute for Highway Safety (IIHS).

Since 2004, ANCAP and IIHS have subjected 42 hybrid and electric drivetrain vehicles to a variety of crashworthiness tests including both moderate and small overlap front crashes, side crashes, and roof strength tests. Crashworthiness results are summarized with special attention paid to the risk of electrical drive system hazards, and laboratory best practice related to electric vehicle testing is described.

The crashworthiness of hybrid and electric drive vehicles is typically similar to that of vehicles with internal combustion engines. IIHS has assigned eight good ratings, three acceptable ratings, and three poor ratings in frontal crash tests (both moderate and small overlap tests); 10 good ratings and one poor rating in side crash tests; and eight good ratings and one acceptable rating in roof strength tests. To date, ANCAP has assigned one 4-star rating and two 5-star ratings to

electric vehicles in its evaluation program. Neither organization observed damage to the batteries or other portions of the electrical drive systems that indicated a potential risk.

Safety precautions and inspections of the electrical systems have evolved to include post-crash checks for isolation of high voltage from the chassis, leakage of volatile gases, and physical damage of the systems. In addition, vehicles are quarantined and observed after a test to ensure hidden damage does not result in fire risk developing over time.

Ten years of crash testing electric/hybrid vehicles by ANCAP and IIHS, covering a wide range of crash conditions, indicates the variation in crashworthiness performance of hybrid/electrical drive vehicles is comparable with the variation observed with conventionally powered vehicles. Neither ANCAP nor IIHS has observed problems associated with the electrical drive systems in tests of more than 40 hybrid and electrical vehicles. This observation suggests safety designers are providing good protection of the electrical drive systems in crashes represented by federal and consumer information tests.

While vehicles with high-voltage batteries present unique challenges to laboratory safety, ANCAP and IIHS experience suggests these potential hazards can be managed. Using appropriate tools and taking extra steps to ensure isolation of the battery from other parts of the vehicle has resulted in the successful execution of electric vehicle crash tests by both organizations without injury or other dangerous incident.

PAPER NO. 15-0328-W

Vehicle Safety Trends and the Influence of NCAP Safety Ratings

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ABSTRACT

In 1999 the Australasian New Car Assessment Program (ANCAP) aligned its test and assessment protocols with Euro NCAP and began issuing safety ratings, with a maximum rating of 5 stars. In effect, to achieve 5 stars, the vehicle needed good frontal offset crash test performance and good head protection in intrusive side impacts. The rating system awards bonus points for intelligent seat belt reminders and, recently, requires certain safety features such electronic stability control (ESC) and emergency brake assist (EBA).

The proportion of models achieving a 5-star safety rating has gradually increased from zero in 2002 to an estimated 75% of models on sale in 2014. This paper presents an analysis of trends with safety ratings and the uptake of key safety features during this period.

This paper also provides estimates of future savings due to the penetration of 5-star vehicles into the Australian vehicle fleet.

Integrated Safety from Pre-Crash to Crash to Post-Crash Chairperson: Stephen Ridella, United States; Jac Wismans, The Netherlands

PAPERNO.15-0295-W

Automatic Opening of Emergency Windows by Magnetic Release Mechanism

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Abstract
The main objective is to facilitate quicker and safer evacuation of passengers in case of frontal and rear impact of bus by automatic opening of emergency windows. The integrated magnetic release mechanism controlled by various sensors like piezo sensor, accelerometer sensor, temperature sensor and poison gas sensor installed at various locations inside the bus, helps in releasing the emergency windows during an impact. This reduces the time the passenger takes to exile the bus as the need for break opening of the windows is avoided. This system also facilitates increased number of exit points for the passengers by changing all windows into exit windows. At normal situations, the metal beaded windows are held firmly in position by the magnet, whereas during impact it releases the windows without damaging them which increases the longevity of the system.

PAPERNO.15-0310-W

Occupant Protection Performance in Side Impact Collisions Preceded by Pre-Crash Deployment of on-Board Safety Systems

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ABSTRACT
This paper presents a simulation methodology for developing new automotive safety systems in an integrated manner that ensures optimal exploitation of benefits of predictive sensing and occupant restraints.
The investigation was performed using the combination of available simulation techniques for modeling Advance Driver Assistance Systems (PreScan software) and simulating the behavior of dummies and real humans under certain load conditions (MADYMO software and Active Human Model (AHM)).
The methodology was applied to investigate the occupant protection in side impact collisions making use of pre-crash deployed safety systems, such as pre-crash thorax airbag, inflatable seat bolsters, movable seat and a combination of them. The impact load on the dummy was derived from the simulation of the full FE vehicle under Euro NCAP Side Impact Testing protocol conditions.
The results obtained showed the clear potential of adopting an integrated safety system for side impact protection applications. When the collision is detected in advance the time gained can be exploited to increase the overall occupant protection by deploying safety countermeasures prior to the crash. Keeping the occupant further from the intrusion zone, reducing the relative impact velocity and controlling the occupant motion when entering the in-crash phase were key to significantly reduce the injury risk.
To realize the above phenomena, different pre-crash concept occupant motion solutions were defined and investigated: pre-crash deployed thoracic airbag, pre-crash deployed side-bolsters and pre-crash deployed laterally moving seat. Additionally combinations of each solution were investigated. The simulation analysis showed the best protection is ensured by the system combined of side-bolsters and moving seat deployed before the collision, in which case the overall injury risk was lowered from 130% to 44%, when expressed as values normalized with respect to high performance Euro NCAP limits.

PAPERNO.15-0329-W

A Methodology and Tool Chain to Develop Integrated Safety Systems

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ABSTRACT

This paper presents a methodology that enables designing integrated safety systems. The advantages of the methodology are demonstrated by applying it to a passive safety system that is supplemented by an AEB active safety system. The passive and integrated safety systems are compared through simulations with a set of vehicles and occupants subjected to load cases obtained from regulations. The methodology reveals changes in injury mechanisms and advantages of the addition of AEB.

Assessment of New and Improved Field Data Collection, Analysis and Benefits Assessment Methods

Chairperson: Robert Thomson, Sweden; Bernd Lorenz, Germany

PAPERNO.15-0259-W

Airbag Related Injuries in NHTSA's Crash Databases

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ABSTRACT

The National Highway Traffic Safety Administration (NHTSA) has been monitoring and gathering information on air bag related injuries and fatalities in its data collection programs since air bags were introduced. As frontal air bag technology has progressed from barrier certified (a.k.a. first generation) to sled certified (a.k.a redesigned) and to advance certified air bag systems, there has been a drastic reduction in the number of injuries and fatalities attributed to these air bags. More recently developed air bags designed to protect occupants in side impacts and rollovers also do not appear to pose a serious threat. The purpose of this paper is to describe the evolution of air bag injuries in all types of air bags collected in NHTSA's in-depth investigation and crash report based programs. Additionally, the paper discusses future plans for collection of air bag and injury information as NHTSA's data collection programs are redesigned in the Data Modernization Project.

PAPERNO.15-0269-W

Updated Estimates of Potential Traffic Fatality Reductions with Automatic Collision Notification

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ABSTRACT

This paper updates the earlier work done by Wu, Craig, et al. (2013) that explored the effects of earlier emergency medical services (EMS) through Automatic Collision Notification (ACN) on passenger/driver survivability using Fatality Analysis Reporting System (FARS) 2005-09. In this continuing study the earlier results are updated using recent FARS 2009-2012 data, while additional factors together with ACN are also considered: such as EMS arrival, time to hospital, urban/rural location comparison, occupant age and correlation between EMS factors. Kaplan-Meier estimator is applied to compare the survival rates between two conditions (e.g., earlier versus late EMS notification); Proportional hazard model explores simultaneously multiple risk factors related to traffic mortality. Correlations between notification and EMS arrival are explored and especially in rural area. Based on FARS data from 2009-2012, Kaplan-Meier life curves clearly show the benefits associated with earlier notifications within 1-2 minutes (approximately 1.5-2.0% fatality reduction within a timeframe of 6 hours after crash) and earlier arrivals. The relative hazard ratio associated with collision notification, location and age are obtained from a multiple regression model, and the relatively higher fatality hazard (up to 4% higher) is associated the later notification of more than 2 minutes. This paper obtains the driver/passenger survival probability differences over time under different conditions of collision notifications, EMS arrivals, time to reach a hospital, and crash locations, furthermore, this analysis provides the estimations of lives that could potentially be saved (177 to 244 per year approximately) due to earlier crash notification, or Automatic Collision Notification (ACN).

PAPERNO.15-0287-W

Identifying and Proving Automotive Algorithm Defects and Affecting Recalls

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ABSTRACT

The societal cost in lives lost and injuries sustained from electronic defects, such as occupant size algorithm misclassification and ignition switch failure, was studied. In addition, the societal cost of ineffective production restraint systems in frontal and angled-frontal crashes was evaluated. Fatalities due to electronic defects were compared to the total fatalities from frontal and angled-frontal crashes.

Accident statistics show that, from 2001 to 2013, there were only 50 electronic algorithm defect deaths annually compared to 10,676 deaths annually from frontal and angled-frontal crashes involving vehicles that met the Federal Motor Vehicle Safety Standard (FMVSS) 208 test requirements. Our research indicates that many more deaths would have been prevented in a single year than electronic defects caused in 20 years if certain features of passive restraint systems proposed in the 1970's had been implemented. The same trend applies to injury mitigation.

The research question explored here is: Should "WE" prioritize identifying and repairing:

- algorithm defects that cause only 50 of the 10,676 fatalities annually, or
- ineffective production restraints systems in vehicles compliant with FMVSS 208 test requirements that cause 10,626 of the 10,676 fatalities annually.

Since NHTSA cannot specify design requirements, a simple solution is to substitute for the right and left angled barrier test a compartment angled at 20º to the right and then 20º degrees to the left on a sled simulating a 30 mph crash.

PAPERNO.15-0435-W

A Concept for Naturalistic Data Collection for Vulnerable Road Users Using a Smartphone-Based Platform

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ABSTRACT

This paper presents a smartphone-based platform for large-scale, low-cost, long-term naturalistic data collection aimed at vulnerable road users (VRUs). The approach taken is to collect naturalistic movement data from VRUs based on information from the embedded sensors in high-end smartphones. The Smartphone application, LogYard, developed in the current study, allows the recording of high quality data (tri-axial acceleration and rotation at 100 Hz plus GPS position and velocity each second). This way, large data quantities from ATV drivers' movements during daily use in different use cases, can be transferred from a large number of users and accumulated in a cloud-based server for off-line analysis.

Apart from the description on how data is recorded and managed in the smartphone-based platform, also a procedure on how to include participants to studies and how private integrity issues and informed consent can be handled from a distance is presented.

By means of the presented smartphone based platform, large number of participants taking part in several parallel on-going studies can be easily administered. This makes the platform a powerful tool to use in large-scale, low-cost, long-term studies providing data from large groups of study participants.

The information made available this way can be used to develop automatic crash notification (ACN) systems directed to VRUs based on identifying movements outside what is “normal” for bicyclists, mopedists, motorcyclists and ATV users.

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EDR Data Collection in NHTSA’s Crash Databases

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ABSTRACT

The National Highway Traffic Safety Administration (NHTSA) has been gathering Event Data Recorder (EDR) information in its data collection programs since the late 1990s. The various EDR data elements collected in NHTSA’s crash databases provide insight into the vehicles’ safety systems and actions leading up to a crash. This EDR data will be a key source as focus on crash avoidance countermeasures increase and crashworthiness countermeasures are optimized in the automotive safety community. The purpose of this paper is to describe the evolution of EDR data collection in NHTSA’s in-depth crash investigation programs leading up to the implementation of the Code of Federal Regulation (CFR) 49 Part 563. Additionally, the paper will discuss the techniques used to collect EDR data, and detail future plans for their coding in NHTSA’s crash databases.

PAPERNO.15-0270-W

Real World Analysis of Fatal Rear-End Crashes

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ABSTRACT

In March 2011, the National Highway Traffic Safety Administration (NHTSA) published its Vehicle Safety Rulemaking and Research Priority Plan 2011 – 2013, which described the projects that are the agency’s priority in the rulemaking and research areas in those calendar years. Programs that are priorities or will take significant agency resources included the development of performance criteria and objective tests to support the identification of effective advanced safety technologies that provide a warning of an impending forward collision and/or automatically brake the vehicle.

In support of the Forward Collision Avoidance and Mitigation project listed in the priority plan, an analysis of real-world crash data was conducted to determine the scope of the crash problem and examine the factors that contribute to rear-end crashes in light vehicles. A review of the 2003 – 2012 National Automotive Sampling System-Crashworthiness Data System (NASS-CDS) was conducted for rear-end crashes involving a fatal occupant.

For each crash identified, a review of the accompanying investigation was conducted using a methodology similar to that described by Bean, et al. [2009]. The authors were then able to identify crash characteristics associated with occupants sustaining fatal injuries in rear-end crashes. For each case, primary and secondary factors were assigned as crash attributes which contributed to the fatal injuries to an involved occupant. This review suggests that fatal rear-end crashes are generally attributed to excessive speed at the time of impact. In order to address these crashes with a forward collision avoidance system, a crash alert warning must be timely and any automatic emergency braking must be aggressive to significantly reduce the impact speed to mitigate the severity or prevent the crash from occurring.

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Improving the Swiss National Accident Statistics by Providing AIS Data to Classify Injury Severity

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ABSTRACT

To provide more detailed data on the injury severity of persons involved in a traffic accident, Switzerland has implemented various measures. The key component was the establishment of AIS coded injury severity data.

Linking the national hospital statistics to the national traffic accident statistics allowed identifying persons that were injured in a police recorded traffic accident. Using information on the diagnosis given in the Hospital statistics (ICD code) the corresponding AIS code was derived. An ICD-to-AIS translator was developed, mapping the medical information to corresponding AIS codes. Since not all ICD codes correspond to a unique AIS code the translator made use of additional medical information in order to map as many cases as possible.

Applying the translator to the data sets of 2011 and 2012, a MAIS could be derived for approximately 95% of all cases. Using the newly implemented procedures, it is now possible to report the share of MAIS3+ injuries sustained on Swiss roads.